EFFECTS OF LASALOCID OR MEAT MEAL SUPPLEMENTATION ON NUTRIENT DIGESTION AND SUPPLY IN CATTLE GRAZING WHEAT PASTURE

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GRAZING WHEAT PASTURE

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CHAPTER I

INTRODUCTION

Supplementation of stocker cattle[1] grazing small grains pastures can increase profits in stocker cattle enterprises. Although many factors, such as type of cattle, forage availability, weather and cattle price movements influence profitability of stocker cattle enterprises, management during the grazing season remains of critical importance. Supplementation of cattle grazing small grains pastures is a management practice with certain advantages (Wagner et al., 1984). Some of these advantages include: 1) increased daily weight gains, 2) increased carrying capacity, 3) extended grass during periods of shortage or adverse weather, 4) carrier for feed additives such as antibiotics and ionophores, 5) supply deficient nutrients.

Depending on the facilities of the stocker cattle operator, several types of supplementation programs can be employed. Feeding silage to stocker cattle on wheat pasture when forage supply is limited can increase stocking density

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[1] The term stocker cattle refers to weaned beef cattle that are grown to heavier weights before placement in feedlots.

so that wheat pastures can be better utilized during the period of spring growth (Vogel, 1985).

Feeding small quantities of grain to stocker cattle grazing small grains pastures can increase weight gains, but efficiency of feed utilization usually is low (9.2 lb feed/lb increased gain); this limits the potential for increasing profitability (Elder, 1967). However, when small quantities of grain are fed, they can carry ionophores, poloxalene and(or) minerals. Both monensin (Horn et al., 1981) and lasalocid (Andersen and Horn, 1987) have increased weight gains of wheat pasture stocker cattle. Andersen and Horn (1987) reported that lasalocid did not influence forage intake or organic matter digestibility, although they observed only slight changes in rumen ammonia and molar proportions of ruminal volatile fatty acids. The mechanism by which lasalocid increases performance of wheat pasture stocker cattle remains unclear. Much of the research with lasalocid has concentrated on effects on ruminal fermentation and interactions with mineral utilization. Surprisingly little data are available on effects of lasalocid on site of digestion of nutrients. Therefore, part of the research presented in this dissertation was to evaluate the effect of lasalocid on site and extent of digestion of nutrients by cattle grazing wheat pasture.

A primary conclusions from the National Wheat Pasture Symposium was that growth of rapidly growing stocker cattle grazing wheat pasture may be limited by inadequate supply of

nonammonia nitrogen to the small intestine (Beever, 1983). Although wheat forage often contains greater than 20% crude protein, wheat forage nitrogen is quite soluble and rapidly degraded in the rumen (Zorrilla-Rios et al., 1985). Vogel et al. (1988) reported that wheat forage nitrogen in the rumen, existed in two pools. The soluble pool comprised 74% and 55% of total forage N that disappeared from in situ bags in the rumen at a rate of 17.5%/h and 16.1%/h in immature and mature forage, respectively. The second nitrogen pool (26% and 45% of total forage N) disappeared at 3.1%/h and 2.1%/h in immature and mature forage, respectively. Including a protein with high ruminal escape in supplements of cattle grazing wheat pasture has increased weight gains by 0.1 kg/d (Anderson et al., 1987; Lee et al., 1985; Horn et al., 1987). The second objective of the research presented in this dissertation was to examine the effects of a supplemental high escape protein, meat meal, on forage intake, site and extent of nutrient digestion and nitrogen balance of cattle grazing winter wheat pasture.

Finally, the recent National Research Council publication, Ruminant Nitrogen Usage (1985) discusses several new sophisticated systems for predicting protein degradation and supply in ruminant animals. Nearly all of these systems require estimates of extent of ruminal protein degradation and passage rate. We would expect that the nitrogenous components (i.e. NPN, soluble N, amino N, etc.) and ruminal energy availability of the feedstuffs are

important factors in these systems, however they are rarely measured. Quantitative estimates of these nitrogen components are available for many ensiled feeds; however, they have not been characterized for certain important forages utilized for beef production in the United States. Fluctuation in concentrations of these nitrogen components throughout the grazing season needs study. Characterization of nitrogen components and of nutrient digestion and supply of important forages in European countries has held a high priority in research for many years. Although research results of many pasture supplementation programs for ruminant livestock are available in the United States, surprisingly little data has concerned nutrient digestion and supply from important forages. Basic understanding of the digestion and utilization of forages by growing cattle is necessary before research of supplementation programs can advance beyond the present empirical approach. The information presented in this thesis characterizing nutrient digestion and supply in cattle grazing wheat pasture may be its most valuable contribution toward development of sound supplementation strategies.

CHAPTER II

REVIEW OF LITERATURE

Digestion of High Quality Forages

Before discussing forage utilization by ruminant animals, one must characterize the forage being considered. Cool season forage in the immature state has unique features which should have an impact on its digestion in ruminants. In general, cool season forages are lower in fibrous constituents than warm season forages or conserved forages (Van Soest, 1983). It is assumed that non-fiber constituents are completely digested. Differences in digestibility among forages are related primarily to factors that influence the digestion kinetics of forage fiber (Mertens, 1987). Lag time, rate of digestion, ruminal residence time and fraction of fiber that is indigestible all influence the kinetic characteristics important in fiber digestion. Concentrations of chemical components such as cellulose, hemicellulose and lignin are related to the fractional rate of forage digestion (Smith et al., 1972). Fresh temperate forages generally are lower in cell wall components and higher in soluble components (Van Soest,

1983). Therefore, rate and extent of digestion generally are greater for fresh temperate forage.

Fresh temperate forages in the immature state typically are rich in crude protein, of which a high proportion is available to microorganisms (Ulyatt et. al., 1975). Ruminants grazing these forages typically have more than adequate ruminal ammonia and volatile fatty acid (VFA) concentrations for fiber digestion and microbial growth (Ulyatt, 1971).

Wheat pasture typically is high in moisture and soluble constituents. Horn (1983) reported chemical characteristics of wheat pasture over a 4 year period. Dry matter (DM) contents of wheat pasture ranged from 20 to 45%, crude protein concentrations exceeded 20% of DM, neutral detergent fiber (NDF) concentrations ranged from 30-50% of dry matter, and in vitro dry matter digestibility (IVDMD) exceeded 70% of DM.

Organic Matter Utilization

The entity animals require in greatest quantity is energy. Therefore efficiency of organic matter utilization (OM) is an important factor determining performance of animals on forage diets. Studies examining organic matter utilization in ruminants fed high quality forages under different circumstances are available for many types of forages. Extents digestion of fresh forages and dried or

conserved forages vary (Beever et al., 1976). Only fresh forages will be considered in this discussion.

Ulyatt and Egan (1979) reported that total tract OM digestibilities of 2 varieties of ryegrass (average 3.8% N) exceeded 83%. Ruminal digestion of organic matter was greater than 54%, and over 90% of water soluble carbohydrate and all of the pectin were fermented in the rumen. Total tract cellulose and hemicellulose digestibilities exceeded 89%.

Beever et al. (1985) fed 3 ryegrass forages at 3 levels of intake to growing cattle. They observed a small decrease (about 2%) in OM digestibility as forage dry matter (DM) intake increased from 1.8 to 2.6% of body weight. Level of intake did not influence energy digestibility or cellulose digestibility. In all cases, OM digestibility exceeded 80%, energy digestibility exceeded 74%, and cellulose digestibility exceeded 82%. Organic matter digestion in the rumen ranged from 53 to 62% of intake. Feeding level did not influence ruminal digestion of OM (58, 58, and 59% of intake for low, medium and high levels of intake). Ulyatt and MacRae (1974) observed a slight increase in ruminal OM digestion when intake was increased from 500 to 800 g/day in sheep. However extents of cellulose and hemicellulose digestion were not influenced by level of intake.

Similar values for OM digestion were reported for cattle grazing forage oats (Hogan and Weston, 1968). They observed total tract OM digestibilities as high as 80% of

intake, with more than 80% of cell wall constituents digested in the rumen and nearly 100% of soluble carbohydrate digested in the rumen.

Based on these data, we would expect ruminal digestion of OM of fresh, high-quality forages to be about 60% of intake. Ulyatt and MacRae (1974) reported that 18 to 34% of OM intake was digested in the small intestine and a substantial portion (11 to 15%) of OM of 3 different ryegrass and clover forages was digested in the large intestine.

Studies attempting to predict site of OM digestion based on components of the forage have not been very successful (Ulyatt and Egan, 1979). Extent of ruminal digestion has been related positively to digestible OM intake (Ulyatt and MacRae, 1974), however no other relationship has been demonstrated consistently.

Forage Nitrogen Utilization

Research addressing utilization of nitrogen of high-quality forages in cattle is limited. Summarization of available data is difficult due to interactions between plant species and level of forage intake on ruminal digestion, and post-ruminal flows of nitrogen components.

Unquestionably, growth of young cattle can be limited by the quantity of protein absorbed in the intestine. MacRae and Ulyatt (1974) concluded that differences in weight gains of sheep grazing temperate forages were more

closely associated with differences in protein absorption from the small intestine than with the quantity of main source of energy supply, VFA's produced by microbial fermentation. One of the primary conclusions of the National Wheat Pasture Symposium was that performance of rapidly growing cattle grazing small grains forages may be limited by flow of inadequate amounts of protein to the small intestine even though forage crude protein and digestibility is high (Beever, 1983).

Beever et al. (1985) fed fresh ryegrass or white clover to confined cattle, and observed as much as 30% of the nitrogen consumed was lost in the rumen when nitrogen concentration in the forage was high. This was also observed in cattle grazing perennial ryegrass or white clover (Beever et al., 1986b). High ruminal nitrogen losses tended to coincide with high ruminal ammonia concentrations. Estimates of ruminal degradation of forage protein have been as much as 70% for ryegrass pasture (Ulyatt et. al., 1975), and 91% on bromegrass pasture (Anderson et al., 1988). Beever and Siddons (1986) reported as much as 30% of ingested N from medium to high N forages may be lost before reaching the small intestine. Data reported in this thesis suggest that as much as 50% of ingested N may be lost before the small intestine in cattle grazing immature wheat forage. This high ruminal loss of N may create shortages of protein available to the animal.

Zorrilla-Rios et al. (1984) reported that wheat forage N in the rumen exists kinetically as two distinct pools. The highly soluble pool which makes up 75% of N in immature forage and 52% of mature forage, and a less soluble N pool made up the remainder of the forage N. Rate of N disappearance, time for half of N to disappear and pool sizes are shown below in table 1.

Table 1. Kinetics of wheat forage nitrogen disappearance from in situ ruminal measurements in steers grazing wheat forage at two stages of maturity.

	Stage of Maturity			
	Immature		Mature	
	3-24 h	24-48 h	3-24 h	24-48 h
Rate of N disappearance (%/h)	13.0[a]	2.2[b]	28.1[a]	2.8[b]
Time for half of N to disappear, (h)	5.3[a]	31.6[b]	2.5[a]	24.8[b]
N pool size at 0 h (% of total N)[c]	75.2	15.6	52.2	58.7

[ab] Means of rows within same stage of forage maturity with different superscripts are different (P<.01).
[c] Estimated from the intercepts of each slope.

Ruminal N degradation was substantial. Zorrilla-Rios et al. (1985) speculated that cattle grazing immature wheat forage may have a low supply of non-ammonia N flowing to the small intestine. This is supported by observations of ruminal N loss of about 50% of N intake in steers grazing immature wheat forage (Andersen et al., 1988).

Data of Barry (1981) support the theory that performance may be limited by quantities of amino acids absorbed from the small intestine. Barry et al. (1981) observed lambs fed fresh ryegrass receiving Na-caseinate +

L-methionine infusions in the abomasum had greater protein deposition in both wool ($P<.05$) and body tissues ($P<.01$) even though metabolizable energy intakes were similar. They concluded that protein deposition in lambs fed ryegrass was limited by supply of amino acids to the small intestine relative to ME intake. Amino acids absorbed/day were, respectively, 16 and 25% of ME intake.

Effect of Forage Maturity on Nutrient Utilization

Organic Matter

Changes in chemical composition and nutritive value of forages with increasing maturity have been widely studied. In typical pasture plants, increases in structural components, and decreases in protein, mineral, and ether extract are observed as forage matures (Waite et al., 1964). Forage digestibility typically decreases with advancing maturity (Blaxter et al., 1961). With advancing maturity, we would expect animals to compensate for the reduced energy intake by increasing forage intake and either increasing passage rate through the gastrointestinal tract (GIT) or possibly increasing volume in the GIT. The alternative is exhibiting lower production levels as feed intake becomes limited by bulk fill. Weston and Hogan (1968) observed that sheep spent more time grazing as ryegrass matured. In addition passage rate from the abomasum was increased in greater proportion relative to the passage rate from the

rumen. No differences in rumen volume were observed. The digestibility of OM decreased with advancing stage of maturity from 83.1 to 58.9% in these studies.

Little research on changes in volatile fatty acid (VFA) production at different stages of forage maturity are available. Beever et al. (1986) report total VFA concentration of cattle grazing ryegrass pastures was not influenced by season and averaged 96 mM. The molar proportion of acetate was not influenced by stage of forage maturity, however propionate tended to decline and butyrate tended to increase as forage matured.

Hogan and Weston (1968) studied the effects of advancing maturity on digestion of forage oats in sheep. They observed a typical increase in cell wall contents, cellulose, and lignin, and decrease in cell contents and nitrogen with increasing plant maturity. Total tract organic matter digestibility decline from 80% in the least mature oats to 55% in the most mature oats. Forage intake remained relatively constant throughout the trial with the exception of a large decline in forage intake while grazing the most mature forage. Interestingly, this coincided with a large decrease in cellulose digestibility, substantial decrease in forage nitrogen and increase in forage cell wall content. Surprisingly, there was no affect of forage maturity on ruminal digestion of organic matter, however this may be partially related to relatively small changes in

forage quality during the first three periods of the study, and the reduced intake of the most mature forage.

Nitrogen

Weston and Hogan (1968) observed changes in chemical composition of ryegrass forage similar to the general trends described earlier. As ryegrass matured, they observed that sheep tended to have lower ruminal ammonia concentrations and a smaller ruminal ammonia pool. Decreases would be expected as the forage crude protein intake declined from 36.4 to 8.4 g/day with increasing forage maturity (table 2). Fecal and urinary nitrogen excretion declined with advancing maturity, but nitrogen retention also declined accordingly. The amount of N entering the small intestine per kg of N intake increased with advancing maturity, however total non-ammonia nitrogen (NAN) digested in the small intestine declined rapidly as forage matured from early to mid season. Between mid and late season, the amount of NAN digested in the small intestine appeared to be related to N intake, however some nitrogen conservation through recycling had began to occur in the late season as NAN digestion in the small intestine was greater than N intake. Stage of forage maturity had no effect on the proportion of NAN that arrived at the small intestine that was digested.

Table 2. Effect of increasing forage maturity on nitrogen utilization by lambs fed ryegrass available ad libitum*

	Early Forage	Mid Forage	Late (1965)	Late (1964)
N intake(g/day)	36.4	12.6	14.8	8.4
Feces N(g/day)	8.0	3.9	5.2	3.7
Urine N(g/day)	23.5	7.6	7.6	4.0
N balance(g/day)	4.9	1.1	2.0	0.7
NAN digested in intestines (g/day)	21.5	10.8	13.4	10.6
Urea N in blood (mg/100 ml)	26.2	14.4	16.0	7.3

* From: Weston and Hogan (1968)

Stage of forage maturity and forage quality has been shown to influence nutrient supply. As forage availability or forage N concentration increased with changes in season, flow of NAN to the small intestine also increased on ryegrass pastures (Beever et al., 1986b; Losada et al., 1982). Losada (1982) observed increases in NAN supply as digestible organic matter intake (DOMI) and body weight increased with changes in season on grass pastures. Definitive conclusions in regards to nitrogen digestion and stage of forage maturity are difficult. Forage N concentration and intake are key components in N utilization. Interactions with the changes in chemical composition of forage discussed earlier are undoubtedly important in N digestion with changes in forage maturity.

Influence of Protein Supplementation on Performance of Cattle Grazing High Quality Forages

Pasture supplementation of cattle has long been a practice of producers to increase performance and improve utilization of forage. It has been assumed that protein supplied by lush green forages is sufficient to meet animal requirements, and that energy is most limiting. The major component of growth in young, rapidly growing cattle is protein deposition as muscle. The energy requirement per kg of added weight of these fast growing animals is approximately 12.5 MJ ME/kg, this may be as little as one-half that of fattening cattle (Van Es, 1978). However, the protein requirement (g/kg BW) for a 150 kg steer gaining 1.0 kg/d is 2.5 times greater than the requirement for a 550 kg steer gaining 1.0 kg/d (NRC, 1984). This illustrates the greater importance of protein in diets of growing cattle when compared to that of fattening cattle.

Despite the seemingly high crude protein of green forage, recent research indicates that the amount of protein flowing to the post-ruminal tract may be limiting cattle weight gains under some circumstances. Supplementing cattle grazing brome grass pastures with 0.25 and 0.5 lb/day of escape protein (blood meal and corn gluten meal) increased weight gains of steers by 0.36 and 0.27 lb/day respectively (Anderson et al., 1988). Similar responses to escape protein supplementation have been observed in wheat pasture

stocker cattle (Lee, 1985; Horn et al., 1987; Anderson et al., 1987).

Penning and Treacher (1982) observed that supplementing lactating ewes grazing ryegrass pastures with fish meal increased both milk production and body weight gains over unsupplemented or ewes supplemented with barley and maize starch. Forage intake was not influenced by the fish meal supplement, however tended to be reduced by barley and maize starch, soybean meal, and soybean meal plus fish meal supplements.

In lactating dairy cows grazing ryegrass pastures, energy is normally considered the most-limiting nutrient. However, in dairy cows grazing ryegrass pasture (4.4% N), supplementation with formaldehyde-treated casein improved milk yield ($P<.01$), and milk protein yield ($P<.01$), while milk fat tended to be lower (Minson, 1981). Supplementation with unprotected casein had no affect on milk production, milk fat, and solids non-fat ($P>.05$). These cows were apparently deficient in amino acids at the intestine as untreated casein is highly degraded in the rumen, and apparently not fully utilized in microbial growth. Cows supplemented with untreated casein spent less time grazing, therefore presumably had lower forage intakes. Minson (1981) suggested that reductions in forage intake of these cows were offset by additional energy supplied in the rumen by the unprotected casein.

Brookes (1984) reported that supplementation with formaldehyde-treated casein had no affect (P>.05) on performance of dairy cows grazing ryegrass pastures. Nitrogen balance data confirmed that no additional nitrogen was being incorporated into milk or body tissues. Minson (1981) speculated that if a single amino acid such as methionine was limiting performance of cows grazing ryegrass, supplementation with protected casein may not improve performance. This may be the case in these cows as Rodgers et al. (1979) observed no increases in plasma concentrations of methionine following post-ruminal infusions of casein to lactating cows fed silage, but did observe increases in plasma methionine when casein + methionine was infused.

Effects of Amino Acid Balance on Animal Performance

Ruminant animals, like other animals require specific amino acids that cannot be adequately synthesized in tissues. Amino acid requirements of ruminant animals have been difficult to quantitate because of the intervention of ruminal fermentation, and variation in requirements due to different productive functions (Owens and Bergen, 1983). The purpose of this discussion is not to discuss the essential amino acid requirements of ruminant animals, but rather to review effects of disproportionate amino acid balance and attempt to relate them to studies were

supplementation of ruminant animals with amino acids was examined.

For a detailed discussion of effects of disproportionate amounts of amino acids in non-ruminants the reader is referred to a review article by Harper and Benevenga (1978). Briefly, a disproportion of amino acids refers to several general categories of "imbalances". First, an amino acid deficiency is simply a shortage of one or more essential amino acids relative to the animals requirement. In this type of disproportion, depressed feed intake is generally the adaptive response. The second general type is an amino acid imbalance. This refers to a large imbalance in absorption of amino acids (surplus of one or more amino acid) relative to the requirement and availability of other essential amino acids. The effect is also depressed feed intake and growth rate. The third type would be high protein intake. The affects are minimal as the liver and kidney adapt to the situation and the animal generally eats well and grows at a normal rate.

Research investigating amino acid requirements of ruminant animals is not as extensive as that for monogastric animals, however some data are available. Essential amino acid requirements for ruminants have been estimated by partitioning the maintenance and growth requirements, and combining net deposition of amino acids with an estimated efficiency of amino acid utilization (Burroughs et al., 1974; Hutton and Annison, 1972).

Supplying essential amino acids in the diets of ruminant animals is not necessary for low levels of production. This is because the ten essential amino acids can be synthesized in sufficient amounts from non-protein nitrogen by rumen microbes (Loosli et al., 1949). Schelling et al. (1967) reported that the ratio of amino acids from microbial protein is similar in many respects to that from whole egg protein. However, despite the similarity of the amino acid composition of hydrolysates of individual strains of rumen bacteria and whole egg protein, differences in both total digestibility and the pattern in which amino acids are released from bacteria may result in marked differences in the amino acid pattern available to the animal (Bergen et al., 1967).

Studies on amino acid supplementation of ruminants has concentrated on lysine and methionine supplementation. Positive results in nitrogen retention or performance of animals supplemented with lysine have been reported (Hale et al., 1959), and negative results have been reported (Gossett et al., 1962; Harbers et al., 1961). Similarly with methionine, both positive results (Loosli et al., 1945; Lofgreen et al., 1947) and negative results (Gallup et al., 1952; Nobel et al., 1955; Gossett et al., 1962; Oltjen et al., 1962) have been reported. Variability in results is probably related to differences in diet, and physiological state of the experimental animals.

Unfortunately few studies have measured the effects of amino acid infusion on feed intake. In sheep fed fresh ryegrass, infusion of casein and methionine into the abomasum did not increase ME intake of sheep, however both weight gains and wool growth was greater in sheep infused with amino acids (Barry, 1981). Papas et al., (1974) observed that in lambs fed semi-purified diets, infusion of casein into abomasum increased dry matter intake, nitrogen retention and live weight gains over sheep infused with water. However, an amino acid mixture containing a casein-like amino acid pattern, but devoid of methionine, threonine and lysine depressed feed intake and nitrogen retention. Schelling and Hatfield (1968) also observed increased feed intake and nitrogen retention when casein was infused into the abomasum of lambs fed a purified diet with urea as the sole nitrogen source. Egan (1965) reported similar effects of postruminal infusion of casein with a low quality roughage diet. Papas et al., (1974) concluded that feed intake of growing lambs can be influenced by the amount and pattern of amino acids reaching the small intestine.

Effect of Amino Acid Supply on Acetate Utilization

MacRae et al. (1985) observed a 27% increase in efficiency of metabolizable energy (ME) utilization for fat synthesis in sheep when 30 g of casein was infused daily into the abomasum. They speculated that differences in efficiency of ME utilization of animals fed high-quality

grasses may be related to more NAN absorption from the small intestine relative to ME intake. They suggested that in this type situation, some amino acids are utilized as glucogenic precursors which may provide reducing equivalents for utilization of acetate in fat synthesis. These animals growing on high-N, highly-digestible grasses apparently have a problem clearing acetate because partitioning of acetate into pathways of fatty acid synthesis is limited by the quantity of metabolic intermediates. Acetate is then probably catabolized via the TCA cycle plus some form of futile cycle. In this type of situation, acetate energy is probably lost as heat (MacRae and Lobley, 1982).

Orskov et al. (1979) demonstrated that sheep infused with volatile fatty acids, protein and minerals are capable of efficient utilization of high proportions of acetate at maintenance and twice maintenance levels of energy intake. However, in this experiment protein was infused at two or more times the protein requirement for maintenance. When protein and(or) amino acid intake is greater than the animals requirement, the surplus becomes available for increasing the glucogenic intermediates necessary to maintain efficient utilization of ME when acetate makes up a large portion of the ME available. MacRae and Lobley (1982) calculated that the excess protein or amino acids provided in Orskov's experiments could provide at least 30% extra reduced $NADPH_2$ above that available from glucose metabolism.

Ribeiro et al. (1981) fed high-quality grass hay harvested in the spring or fall to sheep. Nitrogen in feed was 2.21 and 2.69 g/MJ ME intake for spring and fall harvested grass, respectively. Ruminal production rates of acetate, propionate and butyrate were similar, however efficiency of ME utilization above maintenance was 60% greater for sheep fed spring harvested grass. Ribeiro indirectly attributed this to a large N loss (47% of N intake) before the small intestine of sheep fed autumn harvested grass compared to relatively small N loss (18% of N intake) in sheep feed spring harvested grass. This resulted in more NAN (g/MJ ME intake) entering the small intestine and more amino-N uptake by the portal vein. The difference in ME utilization of spring and fall harvested grasses could be attributed to extra glucogenic precursors absorbed in the form of amino acids. This was evident as plasma glucose concentrations were 10% higher in sheep fed spring harvest grass. There were no apparent differences in urinary N excretion of sheep fed the different grasses. We would expect more urinary N excretion in lambs fed spring harvested grass if amino acids were deaminated for use as glucogenic precursors. However, the difference may not have been apparent in this study because of the high ruminal N degradation, and presumably excretion by sheep fed fall harvested grass. Also if we assume greater efficiency of ME utilization corresponds with greater energy retention in tissues, we can assume that a greater quantity of N is also

incorporated into tissues. Although the sheep may have been utilizing excess amino acids for synthesis of glucose, they also would be incorporating more amino acids into tissues, resulting in less urinary N excretion.

The concept that additional amino acids can improve efficiency of ME utilization has been further examined by Black et al. (1987) in a computer simulation model of metabolism. Their calculations indicated that for diets were acetate provided 76-85% of absorbed energy, elevation of protein from 10 to 20% of absorbed energy resulted in more efficient utilization of acetate. However, increased amino acid absorption did not exert its effect on efficiency of acetate utilization by increasing lipid synthesis, rather by increasing protein deposition. Based on the data of Tamminga (1982) the low protein diet in this study was probably deficient in protein. Subsequent studies indicated that as protein was increased above 15% of energy intake, protein deposition stabilized and efficiency of ME utilization continued to decline as urea synthesis increased (Black et al., 1987). However in these studies glucose and glucogenic precursors inputted into the model were adequate for synthesis of reducing equivalents.

Barry (1981) observed lambs fed a predominantly fresh ryegrass pasture and abomasally infused with casein and methionine had greater rates of protein deposition in tissues and wool than control lambs. Energy deposited as protein was considerably greater (41 vs. 27% of total energy

deposited) in protein infused lambs. Although efficiency of ME utilization and total energy retention were not influenced, composition of weight gains was shifted toward more protein and less fat deposition when protein was infused. The reduction in body fat content and increase in protein content induced by supplementing protein was similar to that predicted by Black (1976).

It is important to remember that under most circumstances amino acids would not be expected to play a critical role as energy sources. However, in situations were rapidly growing animals are consuming high N forages and acetate is the dominant end product of ruminal fermentation, a condition may exists were amino acids are used for synthesis of reducing equivalents. In this case, efficiency of ME utilization can be increased by shunting excess acetate into synthesis of fatty acids. Another possibility is that extra amino acids presented at the small intestine stimulate protein deposition and thereby increase efficiency of ME utilization by altering composition of body weight gain.

Protein as a Glucogenic Precursor

At first sight, to discuss utilization of protein as a energy source seems bizarre. It is not that there are any particular problems in accepting the concept, because protein is typically an expensive component of a livestock rations, it seems a wasteful idea. Because protein intakes

of cattle grazing high-quality fresh forages are generally higher than requirements for total protein, protein possibly makes an important contribution to the energy supply either as VFA's from ruminal fermentation, or by furnishing glucogenic amino acids.

As previously discussed, large amounts of acetate are typically produced from ruminal fermentation of forages. Acetate has many metabolic fates, the major fates being (1) metabolism through the TCA cycle and (2) conversion to long chain fatty acids. The synthesis of long chain fatty acids requires reducing equivalents in the form of $NADPH_2$ (Rawn, 1983). Glucose normally provides the carbon for lipogenesis in nonruminant tissues. Reduced NADPH is synthesized by oxidation of glucose through the hexose monophosphate pathway and by decarboxylation of malate via the citrate cleavage pathway. Ballard (1969) demonstrated the primary carbon source for lipogenesis in ruminant tissues in the absence of glucose is acetate, which is the main product of ruminal fermentation of forage diets. When acetate is the dominant end product arising from ruminal fermentation, $NADPH_2$ levels may become inadequate for maintenance of efficient energy utilization. Studies of differences in concentration of glucose in carotid and portal blood have indicated that there is little or no net gain of glucose from the alimentary tract of sheep given roughage rations (Annison et al. 1957). Ballard (1969) suggested that under normal physiological conditions in ruminant animals, enough

glucose, presumably from absorbed glucose and glucose precursors, may be metabolized via the hexose monophosphate shunt to provide adequate amounts of $NADPH_2$. Therefore, glucogenic precursors provide nearly all the glucose necessary for $NADPH_2$ synthesis. Leng et al. (1967) reported that more than 50% of glucose synthesized in ruminant animals arose from propionate absorbed from the rumen. Other VFA's, glucogenic amino acids, VFA's absorbed from ileal fermentation and (or) absorbed glucose would make up the remainder of the glucose. In high forage diets were ruminal propionate synthesis is relatively low, the availability of glucogenic precursors may have a significant influence on efficiency of utilization of metabolizable energy.

Endocrine Effects of Protein Supplementation

As discussed earlier, Barry (1981) observed increased protein deposition in lambs receiving abomasal infusions of protein while grazing predominantly ryegrass pastures. Associated with increased protein deposition were increased concentrations of insulin, glucogon and triiodothyronine (T_4) in blood, and decreased concentrations of growth hormone.

Insulin has been reported to be anabolic as far as protein metabolism is concerned. It stimulates amino acid transport plus RNA and DNA synthesis (Buttery, 1983). However, Trenkle and Topel (1978) reported insulin was

positively correlated (r=.70) to amount of carcass adipose tissue and negatively correlated (r=-.59) with amount of carcass muscle in growing steers.

Plasma growth hormone concentrations are not closely correlated to total body growth rate of cattle, although the average daily secretion of growth hormone has been positively correlated (r=.42) with growth of carcass lean tissue and negatively correlated (r=-.59) with carcass adipose tissue (Trenkle, 1977; Trinkle and Topel, 1978). Barry (1983) concluded from his data and data of Hart et al. (1978 and 1979) that low concentrations of growth hormone relative to insulin, accompanied by high T_4 concentration is associated with increased growth rate and improved protein deposition. However, Hart et al. (1978 and 1979) obtained data from lactating cattle. Important differences in physiological status of growing and lactating animals may have been ignored with this conclusion. Increase protein flow to the small intestine has been shown to increase plasma growth hormone status in lactating ewes (Barry, 1980), lactating goats (Oldham et al., 1978), and lactating cows (Oldham 1982). Because little comprehensive data is available regarding endocrine changes relative to protein metabolism of growing ruminants on high quality pastures, generalizations regarding endocrine changes with protein supplementation would be premature.

Summary

Fresh temperate forages in the immature state have been classified as generally being high in moisture, crude protein and digestibility. Factors such as stage of forage maturity can have important influences on digestion through changes in structural and chemical composition of the forage. Although crude protein levels are high in fresh temperate forages, they are often highly degradable in the rumen. Loss of nitrogen between ingestion and the small intestine can be as high as 50%. This may result in insufficient quantities of amino acids flowing to the small intestine. Supplemention of cattle with protein feeds of low rumen degradability, such as meat meal, offers potential for increasing the quantity of amino acids available for absorption from the small intestine. Increased performance noted in cattle supplemented with ruminal undegradable protein may be related to several mechanisms. Improvement of amino acid balance and(or) supply in digesta flowing to the small intestine may increase performance by increasing forage intake and protein deposition. Secondly, amino acids absorbed from the gut can serve as glucogenic precursors that are utilized to improve efficiency of acetate utilization in cattle fed forage diets where acetate is the primary source of energy available to the animal. Effects of protein supplementation on hormone status of animals may

also play an important role in the increased forage intake and performance of cattle supplemented with protein sources of low rumen degradability.

CHAPTER III

EFFECT OF LASALOCID ON FORAGE INTAKE AND SITE AND EXTENT OF NUTRIENT DIGESTION OF STEERS GRAZING WINTER WHEAT PASTURE AT TWO STAGES OF FORAGE MATURITY

ABSTRACT

Eight multicannulated Hereford steers grazed a common wheat pasture received either 0 or 300 mg lasalocid$\cdot$head$^{-1}\cdot d^{-1}$. When the forage was immature, lasalocid decreased (P<.10) forage organic matter (OM) intake (g/kg BW) by 10%. Lasalocid decreased (P<.05) the proportion of OM and N digested in the rumen; and reduced N loss between ingestion and the small intestine. Hence more forage N escaped ruminal fermentation and passed to the small intestine (P<.10). When lasalocid was fed, a greater proportion of consumed OM and N intake was digested in the small intestine (P<.10) which increased the ratio of NAN absorbed per kg digestible organic matter intake (P<.10). With mature wheat forage, lasalocid also decreased (P<.10) forage OM intake by 12%, and resulted in reduced ruminal digestion and increased digestion of nutrients in the small intestine as noted with immature forage. The improved performance of growing cattle on immature wheat forage fed supplements containing lasalocid may be partially attributed to 1) a shift in

digestion of OM and N from the rumen to the small intestine, 2) less ruminal degradation and subsequent loss of forage protein, and 3) greater intestinal NAN absorption per unit of digestible organic matter intake.

(Key Words: Lasalocid, Beef Cattle, Wheat Pasture).

Introduction

Lasalocid is a polyether ionophore that improves performance of cattle fed forage (Thonney et al., 1981; Spears and Harvey, 1984). Andersen and Horn (1987) reported that supplementing wheat pasture stocker cattle with 200 mg lasalocid·head^{-1}·d^{-1} increased weight gains of wheat pasture stocker cattle by approximately 0.11 kg/d, however did not observe any differences in forage intake or organic matter digestibility, and only small changes in molar proportions of volatile fatty acids and the acetate:propionate ratio. Speers and Harvey (1984) also observed only minor changes in molar proportions of volatile fatty acids, and slight reductions in the acetate to propionate ratio in cattle grazing mixed orchard grass, fescue, and ladino clover pasture. Thivend et al., (1983) reported decreased ruminal degradation of dietary protein when lasalocid was included in the diet. Katz et al. (1986) observed reduced ammonia and gas production in vitro with alfalfa as the substrate and concluded that microbial activity was reduced. In addition Fuller and Johnson (1981) reported that lasalocid

tended to reduce ammonia production in vitro with both roughage and concentrate substrates. In vivo work indicates that lasalocid did not influence ruminal ammonia concentration of cattle fed forage diets (Speers and Harvey, 1984; Andersen and Horn, 1987), however, in these studies the total ammonia pool size was not measured. Lasalocid has been shown to increase total tract digestibility, (Funk et al., 1986); or not alter total tract digestibility (Paterson et al., 1983; Ricke et al., 1984). Darden et al. (1985) and Zinn (1987) reported that including lasalocid in high concentrate diets of steers had little or no influence on site of digestion of organic matter or starch, or degradation of dietary protein. However, knowledge of effects of lasalocid on nutrient digestion and supply in cattle fed high quality forage diets is limited. In fact, information on nutrient digestion and supply from high quality forages, and especially wheat forage is limited. Zorrilla-Rios et al. (1985) reported that wheat forage N is very soluble and rapidly degraded in the rumen and speculated that subsequent loss of ammonia N may result in shortages of amino acid supply. The present study was conducted to 1) determine the effects of lasalocid of forage intake and site and extent of nutrient digestion of steers grazing winter wheat pasture, and 2) characterize site and extent of nutrient digestion by cattle grazing wheat forage. Effects of lasalocid on ruminal fermentation in these trials was reported by Andersen and Horn (1987).

Experimental Procedure

Steers. Eight mature Hereford steers fitted with ruminal, and t-type duodenal and ileal cannulas were used to study the effects of lasalocid on forage intake and site and extent of nutrient digestion. Steers were given gelatin capsules that contained either 0 (control), or 300 mg lasalocid. The steers grazed a common wheat pasture during the spring grazing seasons of 1984 and 1985. Effects of lasalocid on forage intake and site and extent of nutrient digestion were measured while steers grazed either immature wheat forage or mature wheat forage. The steers weighed 375-420 kg and 457-539 kg while grazing immature and mature wheat forage in year 1, respectively, and 443-516 kg and 532-614 kg while steers grazed immature and mature wheat forage in year 2, respectively.

Forage. Wheat variety TAM-105, fertilized with 112 kg N/ha in the form of anhydrous ammonia was utilized during each year of the study. Forage intake and site and extent of nutrient digestion was measured while steers grazed immature and mature wheat forage. Immature forage was characteristic of rapidly growing forage in the early spring; mature forage was characteristic of wheat forage shortly after heading and represented the forage during the "graze-out" period.

Design. Steers were randomly allotted to two treatments in a split plot experimental design (Steel and

Torrie, 1960) with steers as main units. Observations were made on each animal in each of two experimental periods, in each of two years.

Experimental Periods. The steers grazed wheat pasture during the entire spring grazing season of 1984 and 1985. Steers received supplemental lasalocid for at least two weeks prior to each sampling period. Collection periods were March 19-26 and May 7-14 in year 1; and March 19-26 and April 30-May 6 in year 2. Chromic oxide (8 g/d) was given in gelatin capsules twice daily (0800 and 2000) and was utilized as a nutrient flow and fecal output marker. Particulate and liquid rate of passage were determined using Yb-labeled wheat forage (Teeter, 1981) and cobalt-EDTA (Uden et al., 1980), respectively. Each steer received approximately 500 mg Yb/d on 100 g Yb-labeled wheat forage, and 80 ml of Co-EDTA (3.1 mg Co/ml) per day. Markers were placed directly into the rumen at 0800 and 2000 for 7 d prior to and during the entire collection period. In year 1, the sampling schedule consisted of a 2 d fecal sampling period where samples were taken at 0700, 1300 and 1900 on the first day; and 1000, 1600 and 2200 on the second day. This was followed by a 2 day duodenal and ileal sampling period with a similar schedule. In year 2, sampling periods consisted of a 72 h fecal sampling period where a fecal sample was taken from the rectum every 9 h such that every third h of a 24 h period was represented. This was followed by a similar 72 h duodenal and ileal sampling period.

Following duodenal and ileal sampling in each year, fecal samples were taken at 3, 6, 9, 12, 18, 24, 36, 48 and 60 h after the last marker dose to determine particulate and liquid rate of passage. On the last day of the experimental period, ruminal fluid was obtained from each steer via rumen cannula. Rumen fluid samples were strained through four layers of cheesecloth and stored on ice until rumen bacteria could be isolated by differential centrifugation.

Three hand clipped forage samples were taken twice during each experimental period in each year. Samples were frozen and subsequently lyophilized. During each experimental period, forage availability was determined by clipping three plots (0.341 M^2) at ground level from random locations from within the experimental pasture. Samples were dried at 60 C, and dry weight of forage taken from plots was used to calculate total forage dry matter available to the steers.

Analytical Procedures. Fecal samples were dried at 60 C and ground through a 2-mm screen in a Wiley mill. Duodenal and ileal samples were lyophilized, ground in a coffee mill and composited on an equal weight basis by animal within each period. Chromium concentration of fecal, duodenal and ileal samples was determined by atomic absorption spectophotometry as described by Williams et al., (1962). Concentrations of Yb and Co in fecal samples was determined by atomic absorption spectophotometry by the procedure of Hart and Polan (1984).

Forage dry matter digestibility (DMD) was determined in vitro by a modification of the procedure described by Tilley and Terry (1980). Modifications consisted of adding 1.0 g urea liter of buffered rumen fluid, acidifying with 2.4 N HCl after incubation in buffered rumen fluid and filtering contents of the digestion 24 h later through No. 4 Whatman filter paper following a 24 h pepsin digestion. In vitro dry matter digestibility was measured using rumen fluid from two steers, one on the control treatment and the other steer on the lasalocid treatment, to calculate forage intake for each treatment group, respectively.

Nitrogen in forage, duodenal, fecal and ileal samples was determined by Kjeldahl (AOAC, 1975). Duodenal and ileal samples reconstituted with 0.1 N HCL (20% w/v) were analyzed for ammonia-N (Broderick and Kang, 1980). Non-ammonia nitrogen (NAN) was calculated by difference between total N and ammonia N concentrations. Ruminal bacteria were isolated by differential centrifugation. Samples were centrifuged at 5000 x g to remove suspended particles, then at 20,000 x g to isolate bacteria. Isolated bacteria were then rinsed once with 20 ml of 0.9% w/v NaCl and centrifuged at 20,000 x g to improve purity of the isolated bacteria. Bacteria pellets were lyophilized and ground in a coffee mill. The proportion of bacterial N in duodenal samples was determined by the procedure of Zinn and Owens (1986) using isolated bacterial and duodenal samples.

Nonprotein nitrogen of wheat forage (NPN) was determined by difference between total N and protein N precipitated in a solution of equal volumes of 1.07 N H_2SO_4 plus 11.2% (w/v) Na-tungstate solution (12 h at 5 C). Soluble N was determined as N soluble in the mineral mixture (2% v/v; pH=6.5) of the "Ohio" in vitro fermentation media (Johnson, 1969). Soluble carbohydrates were determined by the procedure of Balwani (1965).

Calculations. Fecal output and nutrient flows were calculated using chromium ratios in feces, duodenal and ileal digesta as follows:

$$\text{Fecal output} = \frac{\text{daily dose of marker}}{\text{Marker concentration in feces}}$$

Flow of digesta to duodenum or ileum=

$$\frac{\text{daily marker dose}}{\text{Marker concentration in digesta}}$$

Nutrient Flow= Flow of digesta x Nutrient concentration

Particulate and liquid rate of passage were determined as the negative slope of the logarithmic decline in fecal marker concentrations over time.

Statistical Analysis of Data. Data were analyzed by least squares analysis of variance. The model for analysis of data for immature and mature forage included lasalocid treatment (TRT), animal within TRT, year and year by TRT interaction as sources of variation. Data of immature and mature wheat forage were not compared statistically because of differences in forage intake and its subsequent effect on

site and extent of digestion. Years were considered to be random effects. Therefore, treatment effects are averaged over years to provide the treatment means of interest. Treatment was tested using animal within TRT as the error term. Year and the year by TRT interaction was tested using the residual error.

Results and Discussion

Chemical composition of wheat forage is shown in table 1. Wheat forage composition was typical. Dry matter averaged 24% and 25%, crude protein averaged about 25% and 12% of DM, and in vitro dry matter digestibility averaged 76% and 66% for immature and mature wheat forage, respectively. In immature wheat forage, soluble N was 27% and 36% of total N; and NPN was 10% and 11.5% of total N in years 1 and 2, respectively. In mature wheat forage, soluble N was 34% and 46% of total N; and NPN was 10% and 15% of total N in years 1 and 2, respectively. Johnson (1973 and 1974) reported that NPN values of wheat forage ranged 13 to 36% of total N during the wheat pasture season.

Effects of lasalocid on forage intake and site and extent of nutrient digestion are shown in table 2. Data from one steer were deleted from analysis because of problems associated with the intestinal cannulae.

With immature forage, addition of 300 mg lasalocid$\cdot$head$^{-1}\cdot$d^{-1} tended to decrease ($P<.10$) OM intake

when expressed as g/kg BW. Nitrogen intake (g/d) was also slightly lower, but not significantly (P>.10) lower. Gutierrez et al. (1982) observed that lasalocid reduced forage intake and increased feed efficiency in growing cattle fed silage based diets. Zinn (1987) observed a 6.5% reduction in feed intake of growing-finishing steers fed corn diets with lasalocid. However, Andersen and Horn (1987) did not detect any reduction in forage intake of wheat pasture stocker heifers supplemented with either 100 or 200 mg lasalocid$\cdot$head$^{-1}\cdot$d^{-1}. Also Thonney et al. (1981) did not detect any effect of lasalocid on intake of cattle fed alfalfa cubes.

With immature forage lasalocid decreased (P<.05) true ruminal digestion of OM and N by 13% and 19%, respectively. Microbial efficiency (g bacterial N/kg OM truly digested) was greater (P<.05) in steers fed lasalocid. However, forage protein degraded per kg OM truly digested in the rumen was not influenced by lasalocid (P>.20). Forage nitrogen loss before the duodenum tended to be lower (P<.10) in cattle receiving lasalocid. Nitrogen loss before the small intestine was 37.7% and 23.4% for control and lasalocid cattle, respectively. Thivend et al. (1983) reported that lasalocid reduced ruminal microbial degradation of feed protein in sheep. Fuller and Johnson (1981) also reported lower ammonia production in vitro when lasalocid was included with high grain and roughage

substrates, suggesting that feed protein was less extensively degraded by ruminal microbes.

A greater proportion of organic matter flowed to the small intestine ($P<.05$) in cattle given lasalocid. This can be related to a reduced extent of ruminal digestion of organic matter in steers receiving lasalocid. Gado et al. (1986) and Funk et al. (1986) reported that lasalocid reduced ruminal digestion of starch and increased intestinal digestion of starch and NDF in cattle and lambs, respectively, fed high concentrate rations.

In our studies, lasalocid did not influence the total quantity (g/d) of non-ammonia nitrogen (NAN) flowing to the small intestine, although NAN flow per kg of N intake tended to be greater ($P<.10$) in steers receiving lasalocid. The proportion of NAN flowing to the small intestine that was microbial NAN averaged 31%. This is lower than the value of 52% reported by Andersen (1988) for steers grazing wheat pasture. However, true ruminal digestion of forage N and ruminal N loss in our study also was lower than values reported by Andersen (1988). Therefore the lower proportion of microbial N flowing to the small intestine can partially be attributed to dilution from greater forage N passing to the small intestine. Walker et al. (1975) observed that only 41% of NAN flow to the small intestine was of microbial origin in sheep grazing ryegrass. In our study, while steers grazed immature wheat forage, lasalocid

supplementation slightly increased the proportion of microbial N in NAN flow (P<.10).

Organic matter absorption from the small intestine as a proportion of OM intake was greater (P<.05) in steers receiving lasalocid (227 vs. 177 g/kg OM intake). This resulted in a tendency for more organic matter absorption from the small intestine per kg of BW in lasalocid steers (P<.10). Also, NAN absorption from the small intestine per kg N intake tended to be greater in steers receiving lasalocid (P<.10). Non-ammonia nitrogen absorption per kg of digestible organic matter intake also tended to be greater (P<.10) in steers given lasalocid. This may help explain performance responses to lasalocid on wheat pasture. MacRae and Ulyatt (1974) concluded that differences in weight gains among sheep fed ryegrass were attributable differences in protein absorption from the small intestine rather than with energy supply. Infusion of casein into the abomasum of sheep fed ryegrass/clover pastures increased performance of sheep (Barry, 1981). MacRae and Lobley (1982) suggested that acetate utilization by ruminants may be improved by additional quantities of reduced NADP. Glucogenic amino acids are one source of additional $NADPH_2$.

Flow of OM and NAN to the large intestine was not influenced by lasalocid (P>.10). Digestion of nutrients in the large intestine accounted for less than 2% of nutrient intake and was not influenced by lasalocid supplementation.

Total tract particulate and liquid rates of passage were not influenced by lasalocid (P>.10).

With mature forage, lasalocid tended to decrease forage intake by about 12% (P<.10). Similar to effects of lasalocid observed with immature forage, ruminal degradation tended to be reduced and flow of nutrients to the small intestine tended to be increased with lasalocid supplementation. However, the magnitude of these effects were not as great for mature as immature.

A secondary objective of this study was to characterize nutrient digestion and supply in cattle grazing wheat pasture. These measures can be characterized from data of cattle given no lasalocid. While steers grazed immature forage, forage intake averaged 16.9 g/kg body weight (BW). True ruminal digestion of OM and NAN were 650 g/kg of OM intake and 535 g/kg N intake, respectively. Beever et al. (1985) reported apparent ruminal OM digestion of cattle fed ryegrass ranged from 53 to 62% of intake. Similar values were reported by Hogan and Weston (1969) for sheep fed forage oats. Loss of N between ingestion and the small intestine accounted for 37.7% of N intake. Therefore, over 70% of wheat forage N degraded in the rumen was lost. Organic matter and NAN flow to the small intestine were 399 and 623 g/kg of intake, respectively. In cattle fed immature ryegrass at 3 levels of intake, NAN flow to the small intestine averaged 722 g/kg of N intake (Beever et al., 1985).

Absorption from the small intestine while steers grazed immature forage accounted for 177 g/kg OM intake and 394 g NAN/kg N intake. Ulyatt and Egan (1979) reported 18-34% of OM intake was digested in the small intestine of sheep fed fresh ryegrass. In the present study, 63% of NAN flow to the small intestine was absorbed which is similar to values summarized by Beever and Siddons (1984) for cattle and sheep fed high quality forages, and to NRC (1985) N usage estimates for all feeds.

While steers grazed mature forage, forage OM intake averaged 15.7 g/kg of BW. True ruminal digestion of OM and NAN were 625 g/kg of OM intake and 483 g/kg of N intake, respectively. Flow of OM and NAN to the small intestine were 434 and 833 g/kg of intake, respectively. Nitrogen loss before the small intestine averaged 17% of N intake. Therefore about 35% of forage N degraded in the rumen was lost, considerably less than with immature forage. Absorption of OM from the small intestine averaged 128 g/kg of OM intake, while absorption of NAN from the small intestine averaged 508 g/kg N intake.

In summary, immature wheat forage is a high crude protein, highly digestible forage. About 27-46% of total N is soluble N; 10-15% of total N is NPN. Ruminal degradation of N from immature forage was slightly more than 50% of intake. Of the N degraded in the rumen, about 70% was lost before the small intestine. In general, supplemental lasalocid tended to decrease forage intake and shift site of

digestio of OM and N toward the post-ruminal tract. Increase efficiency of nutrient utilization through shifts towards ost-ruminal digestion, and decreases in the acetate to propi nate ratio (Andersen and Horn, 1987), probably can explain major portion of the increased weight gains observed with lasalocid supplementation of growing cattle grazing mmature wheat pasture (Andersen and Horn, 1987). While st ers grazed mature wheat forage, lasalocid effected similar hifts in digestion of nutrients towards the post-ruminal ract, although differences between treatments were not as p onounced as with immature wheat forage.

Table 1. Chemical composition of wheat forage from two stages of forage maturity in two years.

	Year 1		Year 2	
Forage Maturity:	Immature	Mature	Immature	Mature
Number of samples	6	6	6	6
Dry Matter, (DM) %	24.3	22.7	23.3	27.1
Organic Matter (OM), %	92.5	93.7	93.7	95.7
Crude Protein,% of DM	27.19	11.38	24.44	13.19
Nitrogen, % of DM	4.39	2.03	3.91	2.11
Soluble N				
% of DM	1.18	0.69	1.42	0.98
% of total N	27.0	34.0	36.3	46.4
Non-Protein Nitrogen				
% of DM	0.44	0.20	0.45	0.32
% of Total N	10.0	9.9	11.5	15.2
Soluble Carbohydrate,% DM	22.51	34.70	27.11	16.50
IVDMD	75.6	66.4	76.2	65.7
Forage DM Available				
Kg/ha	1844	1758	1627	3908
Kg/100 Kg BW	186	172	160	378

Table 1. **Effect of lasalocid on forage intake and site and extent of nutrient digestion by steers grazing immature and mature wheat forage**

	IMMATURE			MATURE		
Mg/lasalocid/h/d	0	300	SE	0	300	SE
# of Obervations	8	7		8	7	
Body weight, kg	447	459	14.4	523	532	17.9
Forage Intake						
Organic Matter						
kg	7.38	6.78	.277	8.21[b]	7.23[c]	.416
g/kg BW	16.9[b]	15.1[c]	.70	15.7[b]	13.5[c]	.81
Nitrogen						
grams	331	305	13.9	197[b]	172[c]	8.3
True Ruminal Digestion, g/kg Intake						
OM	650[d]	566[e]	19.5	625	566	31.4
N	535[d]	436[e]	29.6	483[b]	296[c]	67.6
Ruminal N loss,%[f]	37.7[b]	23.4[c]	4.87	16.74	3.24	10.401
Deg. N/kg OMTDR	39.3	37. 5	1.10	20.1	14.2	2.40
Flow to Small Intestine						
Organic Matter						
grams	2961	3413	232.0	3400	3303	152.9
g/kg OM Intake	399[d]	493[e]	28.4	434	494	3.9
g/kg BW	6.86	7.73	.647	6.72	6.39	.349
Nitrogen						
grams	207	239	18.1	162	160	12.9
g/kg N Intake	623[b]	766[c]	48.7	833	968	104.0
g/kg BW	.48	.54	.471	.32	.31	.026

Continued.

	IMMATURE			MATURE		
mg/lasalocid/h/d	0	300	SE	0	300	SE
Bacterial N, %	30.7[b]	32.1[c]	.90	43.2[d]	31.3[e]	2.03
Feed N, %	69.3[b]	67.9[c]	.90	56.8[d]	68.7[e]	2.03
Absorption from the Small Intestine						
Organic Matter						
g/kg OM Intake	177[d]	227[e]	18.6	128	187	28.3
% of Flow	43.8	45.1	2.06	25.4	33.7	3.75
g/kg BW	3.07[b]	3.67[c]	.338	1.97	2.35	.277
Non-Ammonia Nitrogen						
g/kg N Intake	394[b]	495[c]	36.8	508	630	91.3
% of Flow	63.0	63.9	1.13	58.3	61.8	3.36
g/kg BW	.308	.361	.0356	.196	.201	.0248
Absorbed Protein:Energy						
g NAN/kg DOMI	17.7[b]	22.4[c]	1.8	12.7	15.9	2.4
Flow to large Intestine, g/d						
OM	1644	1813	119.3	2429	2116	119.7
NAN	74.6	81.3	4.28	63.5	57.6	4.18
Rate of Passage, %/hour						
Particulate	5.07	5.12	.459	6.90	4.55	.928
Liquid	2.86	2.39	.191	5.71	5.14	.673

[a] Standard Error
[bc] Means within stage of maturity differ (P<.10)

CHAPTER IV

The Effect of Meat Meal Supplementation on Forage Intake, Site and Extent of Digestion and Nitrogen Balance of Cattle Grazing Wheat Pasture.

ABSTRACT

The effects of feeding a supplement containing a protein source with high ruminal escape, meat meal, on forage intake and site and extent of nutrient digestion in steers grazing either immature or mature wheat forage, and effect of meat meal supplementation on forage intake and nitrogen balance of growing heifers grazing immature forage was studied. While steers grazed immature forage, meat meal supplementation did not influence forage OM intake ($P>.10$), ruminal OM or nitrogen (N) digestion, flow of OM or N to the small intestine, or post-ruminal digestion of OM or N. While steers grazed mature forage, meat meal supplementation tended to increase ($P>.10$) OM intake, but did not influence ($P>.20$) ruminal digestion of OM or N, or flow of OM and NAN to the small intestine. However, organic matter absorption from the small intestine (g/kg OM intake, % of flow or g/kg BW) was greater ($P<.05$) for steers fed meat meal supplements. Small intestinal NAN absorption (g/kg BW and

g/kg digestible OM intake) was greater (P<.10) in steers fed meat meal supplements. Meat meal supplementation did not influence OM or NAN flow to, or absorption from the large intestine. In nitrogen balance experiments, intake of wheat forage OM, g/kg BW, was increased (P>.20) 39% in trial 1, and 18% in trial 2 by meat meal supplementation. Nitrogen retention of heifers was not influenced by meat meal supplementation. These results suggest that a slight increase in forage intake, possibly as a result of a increased supply or correction of imbalance in amino acids is the primary mechanism by which supplementing growing cattle on wheat pasture with protein supplements of low rumen degradability such as meat meal, has increased performance.

(Key Words: Protein supplementation, wheat pasture, growing cattle).

Introduction

Wheat pasture is a high quality forage that typically contains 20-30% crude protein during most of the grazing season. Because of its high nitrogen content, protein status of growing cattle on wheat pasture has not been considered to limit performance. Beever and Siddons (1986) reported as much as 30% of ingested nitrogen of medium- to high-protein forages may be lost before reaching the small intestine. MacRae and Ulyatt (1974) concluded that differences in weight gains of sheep fed ryegrass appeared

to be associated more closely with differences in protein absorption from the small intestine than with energy supply. Post-ruminal protein infusion has increased weight gains of sheep fed ryegrass-clover pasture (Barry, 1981). A high proportion (74%) of wheat forage nitrogen is highly soluble and rapidly degraded in the rumen (Vogel et al., 1987). Rapid degradation of wheat forage N may result in high losses of ruminal N, and a shortage of amino acids for absorption from the small intestine. Supplementing growing cattle on wheat pasture with a high bypass protein, such as meat meal, has increased daily weight gains by approximately .10 kg (Lee, 1985 and Horn et al., 1987). The objectives of our research were to determine the effect of including meat meal in supplements on site and extent of nutrient digestion and nitrogen balance of cattle grazing wheat forage.

Experimental Procedure

Experiment 1

Steers. Eight mature Hereford and Hereford x Angus steers fitted with ruminal, and t-type duodenal and ileal cannulas were utilized to study the effects of including protein source with high ruminal escape, meat meal, in supplements of steers grazing immature and mature wheat pasture on forage intake and site and extent of nutrient digestion. At slaughter, location of cannulas was checked. Duodenal cannulas were 13 to 18 cm from the pyloric

sphincter and ileal cannulas were 31 to 48 cm from the ileal-cecal junction. The steers weighed 345 to 459 kg and 409 to 536 kg while grazing immature forage in years 1 and 2, respectively; and 431 to 573 kg and 500 to 604 kg while grazing mature forage in years 1 and 2, respectively.

Forage. Wheat forage variety TAM-105, fertilized with 112 kg N/ha in the form of anhydrous ammonia was utilized during each year of the study. Immature forage was characteristic of rapidly growing forage in the early spring. Mature forage was characteristic of wheat forage shortly after heading, and would be representative of the forage available during the grazeout period on wheat pasture.

Design. All steers grazed the same wheat pasture during the spring grazing intervals of 1986 (Year 1) and 1987 (Year 2), and were randomly allotted to two treatments in a split plot experimental design (Steel and Torrie, 1960) with steers as main units, and observations were made on each animal while grazing immature and mature wheat forage (i.e., two periods) in each of the two years.

Supplements. In year 1, steers were fed 900 g daily of either a corn-based, control supplement or a supplement containing approximately 24% (as-fed basis) meat meal (table 1). In the second year, the supplement was formulated and fed at a rate to provide the same amount of crude protein per kg of metabolic body weight in year 1. Supplements (table 1) were formulated to be isocaloric and contain

similar amounts of Ca, P and Mg. Yeast Culture was included in the supplements of year 2 in an attempt to improve acceptance and increase intake of the supplement containing meat meal for cattle of a companion grazing and performance trial on wheat pasture.

Indigestible Markers. Chromic oxide (4 g/d) was dosed in gelatin capsules (1/2 oz.) and served as nutrient flow and fecal output marker (Van Soest, 1983). Ytterbium (Yb) labeled wheat forage (Teeter, 1981) and cobalt-EDTA (Uden et al., 1980) were used to estimate particulate and liquid rate of passage, respectively. Each steer received approximately 100 g of Yb-labeled wheat forage (5.0 mg Yb/g forage) and 80 ml Co-EDTA (3.1 mg Co/ml) per day.

Sampling Procedures. The steers grazed wheat pasture for at least 30 d prior to the first experimental period in each year and remained on wheat pasture the remainder of the grazing season. Each experimental period lasted 22 days. Supplements were fed for at least 14 d prior to each sampling period and during the entire experimental period (days 1-22). Indigestible markers were dosed ruminally twice daily at 0800 and 2000 h starting 7 days prior to the sampling period (days 7-19). Sampling periods consisted of a 72 h fecal sampling period (days 15-17) in which fecal samples (total of 8) were taken from the rectum every 9 h such that every 3rd h of a 24 h period was represented. A similar 72 h duodenal and ileal sampling period (days 17-19) followed fecal sampling. Following duodenal and ileal

sampling, fecal samples were taken at 3, 6, 9, 12, 18, 24, 36, 48 and 60 h after the last marker dose (day 18) to determine particulate and liquid rate of passage (days 19-21). On the last day of the experimental period (day 22) rumen fluid samples were obtained through the rumen cannulae 4 h after feeding supplements. Steers grazed wheat pasture after being fed their supplements (0800) until rumen fluid samples were obtained. Ruminal fluid samples were collected via cannula by hand, using a 250-ml beaker, from four sites within the rumen (i.e., anterior dorsal, anterior ventral, posterior dorsal and posterior ventral sacks). Ruminal fluid samples were strained through four layers of cheesecloth and pH was immediately measured with a pH meter and glass electrode. One hundred ml aliquots of strained fluid acidified with 2 ml 20% sulfuric acid were stored in an ice slurry until ammonia analyses were conducted. Five-milliliter aliquots of strained ruminal fluid were prepared for volatile fatty acid (VFA) analysis by deproteinization with 1 ml of 25% (w/v) metaphosphoric acid that contained 2-ethylbutyric acid as an internal standard. A 250 ml sample of rumen fluid from each steer was stored on an ice slurry for bacterial isolation by differential centrifugation.

Three hand clipped forage samples were taken on days 14 and 19 during each experimental period. Samples were frozen immediately over liquid nitrogen and subsequently lyophilized. During each experimental period, forage availability was determined on day 14 by clipping three

plots (0.341 m^2) to ground level from random locations from within the experimental pasture of 3.5 ha.

Analytical Procedures. Fecal samples were dried at 60 C and ground through a 2-mm screen in a Wiley mill. Duodenal and ileal samples of about 250 ml were lyophilized, ground in a coffee mill and composited on an equal weight basis by animal within each period. Chromium concentration of fecal, duodenal and ileal samples was determined by atomic absorption spectophotometry as described by Williams el al. (1962). Concentrations of Yb and Co in fecal samples was determined by atomic absorption spectophotometry by the procedure of Hart and Polan (1984). Fecal, duodenal and ileal samples taken from an extra steer that did not receive any of the markers was used in preparation of rare earth standard solutions.

In vitro organic matter digestibility of supplements was determined by procedures modified from Tilley and Terry (1963). Modifications consisted of adding 1.0 g urea/liter of buffered ruminal fluid, acidifying with 2.4 N HCL after a 48 h incubation in buffered rumen fluid and filtering contents of the digestion through a Gooch type low form crucible with size C fritted disk following a 24 h pepsin digestion.

The INDF concentrations of fecal and forage samples was determined as neutral detergent fiber (NDF) remaining after a 144 h in vitro incubation (39 C) with 40 ml of buffered rumen fluid that consisted of equal parts (v/v) of strained

rumen fluid and McDougall's buffer (McDougall, 1948). The buffered rumen fluid was modified by adding 1.0 g urea/liter. Residues were analyzed for NDF by the procedure of Goering and Van Soest (1970). Sodium sulfate was deleted from the neutral detergent solution during refluxing of forage samples as suggested by Robertson and Van Soest (1981).

Nitrogen in forage, duodenal, fecal and ileal samples was determined by the Kjeldahl procedure (AOAC, 1975). Duodenal and ileal samples were reconstituted with 0.1 N HCL (20% w/v) and were analyzed for ammonia-N (Broderick and Kang, 1980). Non-ammonia nitrogen (NAN) was calculated by difference between total N and ammonia N concentrations. The proportion of bacterial N in duodenal samples was determined by the RNA procedure of Zinn and Owens (1986) using isolated bacteria and duodenal samples.

Ammonia analyses on rumen fluid was conducted within 2 h of sampling by a modification of the magnesium oxide distillation method (AOAC, 1975) described by Andersen and Horn (1987). Ruminal fluid VFA samples were centrifuged at 25,000 x g for 20 min and the supernatant solution was refrigerated until analyzed for VFA concentrations by gas chromatography. Two microliter samples were injected into a 183-cm, 2-mm I.D.,u-shaped glass column packed with 10% - SP1200/1% H_3PO_4 on 80/100 chromosorb WAW, with nitrogen as the mobile phase at a flow rate of 40 ml/minute. Column, inlet port and detector temperatures were 130, 170 and 175

C, respectively. Ruminal bacteria were isolated by differential centrifugation. Samples were centrifuged at 5000 x g to remove suspended particles, then at 20,000 x g to isolate bacteria. Isolated bacteria then were rinsed once with 20 ml of 0.9% w/v NaCl and centrifuged at 20,000 x g to improve purity of the isolated bacteria. Bacteria pellets were lyophilized and ground in a coffee mill.

Non-protein nitrogen (NPN) of wheat forage was determined by difference between total N and protein N precipitated in a solution of equal volumes of 1.07 N H_2SO_4 plus 11.2% (w/v) Na-tungstate solution (12 h at 5 C). Soluble N was defined as N soluble in the mineral mixture (2% v/v; pH=6.5) of the "Ohio" in vitro fermentation media (Johnson, 1969). Soluble carbohydrates were determined by the procedure of Balwani (1965). A second set of three forage samples obtained from esophageally cannulated on days 14 and 19 steers was assayed for indigestible neutral detergent fiber (INDF) for use as an internal indigestible marker.

Calculations. Fecal output and nutrient flows were calculated using chromium ratios in feces, duodenal and ileal digesta as follows:

$$\text{Fecal output} = \frac{\text{daily dose of marker}}{\text{Marker concentration in feces}}$$

$$\text{Digesta Flow} = \frac{\text{daily marker dose}}{\text{Marker concentration in digesta}}$$

$$\text{Nutrient Flow} = \text{Flow of digesta} \times \text{Nutrient concentration}$$

The computer program for calculating forage intake and nutrient flow is shown in Appendix Table 1. Daily fecal outputs were corrected for indigestibility of supplements in calculation forage intake. Forage organic matter digestibility (OMD) was determined by using INDF concentrations of fecal samples and esophageal forage samples. Forage OM intake was calculated by dividing corrected fecal output by indigestibility of forage OM. The quantity of bacterial N flowing to the small intestine was calculated by multiplying the ratio of total N to nucleic acids of the isolated bacteria by the reciprocal of the nucleic acid concentration in duodenal samples. Nitrogen and nucleic acid concentrations of isolated bacteria are reported by treatment, period and year in appendix table 2. True ruminal digestion of N was calculated by subtracting the forage N flow to the small intestine from N intake. True rumen OM digestion was calculated by correcting the OM flow to the duodenum for bacterial OM flow. Bacteria were assumed to be 80% OM. Particulate and liquid rate of passage were determined as the negative slope of the logarithmic decline in fecal marker concentrations over time.

Statistical Analysis of Data. Data were analyzed by least squares analysis of variance. The model for analysis of data for immature and mature forage included meat meal treatment (TRT), animal within TRT, year and year by TRT interaction as the sources of variation. Data of immature

and mature wheat forage were not compared statistically because of differences in forage intake and its effect on site and extent of digestion measurements. Years were considered to be random effects. Therefore, treatment effects were averaged over years to provide the treatment means of interest. The F-ratio for treatment was tested using animal within TRT as the error term. The F-ratio for year and year by TRT interaction was tested using the residual error mean square.

Experiment 2

Heifers. Eight ruminally cannulated Hereford x Angus yearling heifers were used to study the effects of meat meal supplementation on forage intake and nitrogen balance. The heifers grazed the same wheat pasture as described in experiment 1 from February through March 1987 (trial 1) and from November through December, 1987 (trial 2). The heifers weighed 159-209 kg in trial 1, and 275-364 kg in trial 2.

Design. Heifers were allotted randomly to one of two treatments in a split plot experimental design (Steel and Torrie, 1960) with heifers as main units and observations in two experimental periods made on each heifer in each trial being the split plot.

Supplements. Heifers were fed 900 g/d in trial 1 and 1350 g/d in trial 2 (as-fed basis) of either a corn based (control) supplement or a supplement containing meat meal. Ingredient composition and crude protein contents of the

supplements fed in trials 1 and 2 are shown in table 1. The supplement for trial 2 was formulated and fed at a rate to provide the same amount of crude protein per kg metabolic body weight as in trial 1. Within each trial, supplements were formulated to be isocaloric and contain similar amounts of Ca, P and Mg. Heifers were fed supplements on wheat pasture for at least 2 weeks prior to the initiation of each experimental period.

Sampling Procedures. Experimental periods consisted of (1) one day for adaptation to catheterization and collection bags and harnesses, and (2) four days for collection of total feces and urine. Collection dates were March 9-13, 1987 (trial 1); and November 12-16 and December 2-6, 1987 (trial 2). Data of the second experimental period of trial 1 was deleted because results were extremely variable. This was attributed to the fact that the heifers were fairly small (i.e., about 180 kg). The stress of the collection equipment and previous experimental period hampered normal grazing activity.

Total collection of feces and urine was made by the procedure of Stillwell et al. (1983). Feces were collected from bags every 24 h in trial 1 and every 12 h in trial 2. Total fecal contents were weighed, mixed in a paddle mixer, and subsampled. Approximately 250 g (DM) subsamples were collected and dried in a forced-air oven at 55 C. Subsamples were composited by animal in proportion to the

fecal dry matter output for the day corresponding to the subsample.

Urine bags were emptied every 12 h. Total urine volume was measured, and urine was diluted with water to an exact volume. Aliquots (10% of the final volume) were acidified, composited and stored at 5 C until analyzed for N within 2 d of collection of the last sample.

Three forage samples were during each experimental period, frozen immediately over liquid N and lyophilized for measurements of forage quality as described previously. Three forage samples obtained from esophageal cannulated steers were assayed for indigestible neutral detergent fiber (INDF) for use as a internal indigestible marker to calculate forage intake.

Analytical Procedures. Residual dry matter of fecal samples was determined following drying overnight at 100 C. Organic Matter was determined by subtracting fecal ash remaining after combustion at 500 C for 4 h. Nitrogen content of forage, fecal and urine samples was determined by Kjeldahl (AOAC, 1975) on each subsample. Indigestible NDF was used as an internal marker to estimate forage OM intake. Procedures for INDF determination were described earlier in experiment 1. Fecal outputs for forage intake calculation were corrected for indigestibility of supplements by IVOMD procedures as described in experiment 1.

Statistical Analysis of Data. Data were analyzed by least squares analysis of variance. The model for trial 1

included TRT as the only source of variation. The model for trial 2, included TRT, animal within TRT, period and TRT x period as sources of variation. Animal within TRT was used as the error term.

Results and Discussion

Experiment 1.

Chemical composition of wheat forage during these studies is shown in table 2. Forage dry matter, organic matter, nitrogen, soluble N and nonprotein N (NPN) were typical of wheat forage in there stages of maturity, with the possible exception of slightly lower than normal crude protein of immature wheat forage during year 2. Soluble N averaged 44 and 39% of total N, and NPN averaged 12 and 18% of total N of immature and mature wheat forage, respectively. Soluble carbohydrates and in vitro dry matter digestibility of forage during these experiments also were typical of wheat forage. Variations in composition between years likely can be attributed to a wet spring and large temperature changes during the 1987 grazing season. Johnson et al. (1973; 1974) reported that soluble carbohydrate of wheat forage over the season ranged from 13 to 36% of DM, crude protein from 10 to 30% of dry matter, and NPN from 10 to 20% of total N. With the exception of NPN values being slightly high during year 2 of the study our values match those of Johnson et al. (1973;1974). Forage availability (kg DM/100 kg body weight) ranged from 57 to 179 (year 1)

and from 116 to 276 in year 2, therefore, intake should not have been limited during these studies by amount of available forage (Ellis et al., 1984).

Effects of meat meal supplementation on forage intake and site and extent of nutrient digestion by steers grazing immature and mature forage is shown in table 3. Year was a significant source of variation (P<.05) for many of the measurements. However, the year x treatment interaction was not significant (P>.20) for any measurements from immature forage. While steers grazed mature forage, the year x treatment interaction was not important (P>.15) for any measurement except for nitrogen intake (P<.05). Because the rank of treatment means was not changed the interaction was ignored.

Meat meal supplementation did not influence (P>.05) forage intake or any of the measurements of nutrient digestion and supply from immature forage. Forage organic matter intake averaged 32.8 g/kg BW. Supplementation with meat meal did not influence true ruminal digestion of OM or N. Ruminal digestion of OM and N was high, averaging nearly 80% of intake from immature forage. Apparent ruminal digestion of nutrients of ryegrass forage has been reported to range between 55-75% of intake (Weston and Hogan, 1968; and Beever et al., 1986) in sheep and cattle, respectively.

True ruminal N digestion averaged 794 g/kg N intake, and ruminal N loss was approximately 59% of total N intake while steers grazed immature forage. Therefore, 74% of the

N degraded in was lost from the rumen. Ribeiro et al. (1981) reported that ruminal N losses were as high as 46% while sheep grazed autumn-harvested grass. Beever and Siddons (1984) reported ruminal N losses of nearly 30% in cattle fed medium- to high- N forages, and considered the loss to be high. They suggested that the loss was the result of a dietary imbalance of N:readily soluble carbohydrate. However in our studies ruminal pH was low, averaging only 5.8, and VFA concentrations were high (175 mM), suggesting the presence of more than adequate amounts of fermentable carbohydrates for ruminal fermentation (table 4). Forage N degraded per kg OM truly fermented in the rumen averaged 42.8 g and was not influenced by meat meal supplementation (P>.05). This is similar to the value of 45 g N degraded per kg OM apparently degraded in cattle fed ryegrass (Beever et al., 1985). Beever and Siddons (1984) suggested that 25-35 g of degraded N per kg OM truly digested in the rumen is required for optimal microbial protein synthesis. Our value is considerably higher indicating that forage N degradation was extensive.

Flow of NAN to the small intestine averaged 0.58 g/kg BW. Flow of NAN (g/kg BW) to the small intestine in cattle grazing ryegrass pastures as been reported to range from 0.47 to 0.68 (Losada et al., 1982); and from 0.41 to 0.76 (Beever et al., 1986a). Flow of OM and NAN to, and absorption from the small intestine were not influenced by meat meal supplementation. Considering that 15 g N was

added from meat meal, failure to increase percent escape was disappointing. However, as a fraction of total flow added N from meat meal was very small (<6%). Of the NAN flowing to the small intestine, 52% was of microbial origin. This value is very similar to that reported by Walker et al. (1975) for sheep fed fresh ryegrass forage. Flow of NAN to the small intestine was 20.5 g/kg DOMI. Losada et al. (1982) reported flow of NAN/kg DOMI on ryegrass was 27-41 g/d. Cruickshank et al. (1985) reported an average 39.2 g NAN flowed to the small intestine per kg DOMI in lambs grazing ryegrass pastures. Non-ammonia N absorbed from the small intestine per kg of digestible OM intake (DOMI) average 12.8 g and was not influenced by meat meal supplementation. Our low values may indicate that protein available at the small intestine was deficient relative to digestible intake. Improving the ratio of protein absorbed per unit of energy intake has been shown to improve efficiency of ME utilization by sheep grazing ryegrass pastures (MacRae et al., 1985).

Organic matter and NAN flow to and absorption from the large intestine were not influenced by supplementation with meat meal. Organic matter absorption in the large intestine was less than 50 g/kg OM intake. This is somewhat lower than values for ryegrass and clover pastures. Ulyatt and Egan (1979) observed that between 9 and 18% of DOMI of 4 different ryegrass and clover forages was digested in the large intestine of sheep. Ruminal particulate and liquid

rate of passage averaged 4.0 and 5.0 %/h, and were not influenced (P>.10) by meat meal supplementation.

Mature forage. Feeding steers supplements containing meat meal while grazing mature wheat forage did not influence forage OM or total N intake (P>.15), although intake of forage OM (g/kg BW) was 14% higher. Ruminal digestion measurements were not influenced (P>.10) by meat meal supplementation. Ruminal digestion of nutrients though considerably lower than observed for immature forage, were well within range of apparent ruminal digestion values reported by Weston and Hogan (1968) and Beever et al. (1986a) for high quality forages. About 45% of total N intake was digested in the rumen. Calculated ruminal N losses were about -19% indicating that N recycled to the rumen was being incorporated into microbial protein. Beever et al. (1985) reported ruminal N losses of -15% for cattle fed ryegrass (2.2% N) at later stages of maturity. Nitrogen recycling would suggest a need for more ruminal degraded protein or NPN for steers grazing mature wheat forage. Ruminal ammonia concentration averaged 7 mg/dl in year 1 and 37 mg/dl in year 2. In either year, ruminal ammonia concentration should have been more than adequate for microbial protein synthesis (Satter and Slyter, 1974).

The relationship between 1) the ruminal ammonia concentration and 2) the flow of NAN to the duodenum (g/g N intake) to the N content of wheat forage grazed in these experiments OM is shown in figure 1. The observations from

mature forage of year 2 were not included in the regression equation for ruminal ammonia vs. N:OM because the were atypically high. As N concentration of wheat forage OM increased, 1) rumen ammonia increased, and 2) flow of NAN (g/g N intake) decreased. This relationship was observed by Beever et al. (1986) in steers grazing ryegrass or white clover. Beever et al. (1986) reported that NAN flow to the duodenum was equal to or exceeded N intake when N:OM of forage was less than 27.4 g/kg. In our data, NAN flow to the duodenum of steers grazing mature wheat forage also exceeded N intake. Nitrogen concentration of the mature wheat forage was only 1.9 and 2.4% of OM in years 1 and 2, respectively. Hogan and Weston (1970) reported that when N/DOM was less than about 4%, the amount of NAN that passed from the stomach exceeded N intake. The N:DOM ratio for mature wheat forage in our studies averaged 3.5%, at which NAN flow averaged 1190 g/kg N intake.

Forage N degraded per kg OM truly fermented in the rumen also was considerably lower than observed for immature forage and not influenced by meat meal supplementation ($P>.10$). However, of the NAN flowing to the small intestine, about 52% was of microbial origin. This was quite similar to that observed for immature forage despite less extensive OM digestion in the rumen.

Flow of OM and NAN to the small intestine was similar for steers receiving both control and meat meal supplements. However flow of NAN/kg DOMI was slightly greater in steers

fed supplements containing meat meal ($P<.10$). Absorption of OM from the small intestine was greater ($P<.05$) for steers fed supplements containing meat meal. Although absorption of NAN from the small intestine (g/kg N intake) was not influenced ($P>.10$) by meat meal supplementation, a slightly greater ($P<.10$) percentage of NAN flow to the small intestine was absorbed. In addition, slightly more NAN was absorbed from the small intestine per kg of BW in steers fed supplements containing meat meal ($P<.10$). Non-ammonia N absorption from the small intestine per kg of DOMI was 10% greater ($P<.10$) in steers fed supplements containing meat meal. This may have important implications for improving efficiency of ME utilization (MacRae et al., 1985) as crude protein intake should have been more than adequate to meet protein requirements.

Meat meal supplementation did not influence flow of OM and NAN to, or absorption from the large intestine. Particulate and liquid rate of passage from the rumen averaged 4.7 and 5.8 %/h and were not influenced ($P>.10$) by meat meal supplementation.

Effects of meat meal supplementation on ruminal fermentation measurements are shown in table 4. Meat meal supplementation did not influence ($P>.10$) either ruminal pH, ammonia concentration or molar proportions of acetic, propionic, isobutyric, butyric, isovaleric or valeric acids with either immature or mature wheat forage. Ruminal pH was higher and ammonia concentration in the rumen was lower with

mature forage. Weston and Hogan (1968) observed that sheep tended to have smaller ruminal ammonia pools as ryegrass forage matured; and this was related to lower forage N concentration. In our studies we saw a considerably lower forage N concentration (4.35% vs. 1.82%; and 3.09% vs.2.20% in years 1 and 2, respectively) as wheat forage maturity increased although changes in the ruminal ammonia concentration between immature and mature wheat forage were relatively small.

Experiment 2

Chemical composition of wheat forage during N balance studies is shown in table 5. Forage nitrogen concentrations were similar to values reported for experiment 1. Soluble N and NPN was 24% and 13% of total N in trial 1, and averaged 48% and 22% of total N in trial 2, respectively. Lower N and soluble N concentrations may be related to the unusually large fluctuations in temperature and moisture during the 1987 grazing season.

Effects of meat meal supplementation on forage intake and N balance for trial 1 are shown in table 6. Forage organic matter intake (g/kg BW) tended to be greater (P<.15) and total nitrogen intake was greater (P<.05) for heifers fed meat meal supplements. This was due to 39% greater forage intake, plus slightly greater intake of supplemental nitrogen. Total nitrogen excretion also was greater (P<.06) for heifers supplemented with meat meal; both fecal and

urinary excretion of nitrogen were increased (P<.10). Nitrogen retention (g/d) was greater (P<.09) for heifers supplemented with meat meal, however N retention, expressed as a percentage of either N intake or absorbed N was not influenced by supplementation with meat meal.

Forage intake and nitrogen balance data of trial 2 are shown in table 7. Forage OM intake, expressed as g/kg of body weight was 18% greater (P<.13) with meat meal supplementation and nitrogen intake was 30% greater for meat meal supplemented heifers. Nitrogen excretion also was greater for heifers supplemented with meat meal, however differences were not significant (P>.24). Retention of N (g/d) was numerically greater, however as observed for year 1, supplementation with meat meal did not significantly influence nitrogen retention (P>.24). All nitrogen retention values were unusually high (67-124 g/d) for unknown reasons. Based on regression equations of Broster et al. (1978) using N and DOM intake of cattle, N retention would be expected to be 42-84 g/d.

In summary, including meat meal in supplements of steers grazing immature winter wheat pasture did not significantly influence forage organic matter intake or site and extent of digestion of nutrients. However, supplementation with meat meal tended to increase forage intake (3.7% and 14%) in experiment 1 and in N balance studies (38.6% and 17.9%). Based on equations of the net energy system (NRC, 1984) for a 200 kg medium frame steer

consuming 2.5% of body weight (DM-basis), 7.0% increase in wheat forage intake should increase weight gains by .1 kg/d. This increase in gain is approximately the amount reported by Horn et al. (1987) and Lee (1985). While steers grazed mature forage, OM absorption from the small intestine, and NAN absorption from the small intestine were increased. This resulted in a higher ratio of NAN absorbed from the small intestine per kg DOMI intake which may have increased efficiency of ME utilization. MacRae et al. (1985) observed a 27% increase in efficiency of ME utilization when 30 g of casein was infused into the abomasum of sheep fed ryegrass. Dry matter intake of the sheep in their study was 481-705 g/d and 30 g of casein would provide an additional 4 g of NAN to the small intestine for absorption. In their study, the increase in NAN absorbed per kg DOMI would be less than 1 g/kg DOMI; we observed a increase of 2 g/kg DOMI with meat meal. MacRae et al. (1985) suggested that the increased efficiency of ME utilization they observed may be related to an increased supply of glucogenic amino acids to the small intestine which provide extra reducing equivalents (NADPH) and glycerol phosphate for conversion of acetate to fatty acids. Nitrogen balance trials indicated that supplemental meat meal did not increase nitrogen retention by heifers. These data indicate that supplementation of cattle grazing winter wheat pastures may result in a slight improvement in forage intake. This may be result of an increase or a correction in amino acid balance of NAN flowing to the small

intestine. The greater ratio of NAN absorbed per kg DOMI with mature forage may responsible for higher rates of gain of stocker cattle grazing more mature forages.

Table 1. Ingredient Composition and Crude Protein Content of Supplements (% of Dry Matter).

Item	Control	Meat meal
	Experiment 1 (Year 1)	
Corn	79.0	67.0
Meat meal	--	17.7
Cottonseed hulls	9.0	9.0
Calcium carbonate	2.0	--
Dicalcium phosphate	3.5	--
Magnesium oxide	.6	.3
Cane molasses	4.4	4.4
Trace Mineral Salt	.3	.3
Salt	1.2	1.2
Rumensin premix[a]	.14	.14
Crude Protein		
Calculated	8.1	16.3
Actual	8.3	15.9
DM %, actual	89.3	90.2
	Experiment 1 (Year 2); Experiment 2 (Trial 1)	
Corn	79.3	62.2
Meat meal	--	25.4
Cottonseed hulls	3.8	3.8
Calcium carbonate	2.7	--
Dicalcium phosphate	5.2	--
Magnesium oxide	.7	.2
Molasses	4.2	4.2
Diamond V Yeast Culture	3.0	3.0
Trace mineral salt	.3	.3
Salt	.7	.7
Rumensin premix[b]	.14	.14
Crude Protein		
Calculated	8.3	19.8
Actual	9.7	18.5
DM %, actual	92.2	92.4
	Experiment 2 (Trial 2[c])	
Meat Meal	--	25.0
Corn	91.8	75.0
Dicalcium phosphate	5.1	--
Calcium carbonate	2.7	--
Magnesium oxide	.4	--
Crude Protein		
Calculated	8.7	20.4
Actual	9.6	18.6
DM %, actual	88.5	89.9

[a] To supply 145 mg monensin/kg (as-fed) of supplement
[b] Added to provide 34 mg monensin/Kg of supplement.
[c] Monensin (231 mg/d) provided to all heifers in gelatin capsules.

Table 2. Chemical Composition of Immature and Mature Wheat Forage Grazed by Steers in Experiment 1

Forage Maturity:	Immature	Mature
	·········Year 1·········	
Observations	6	6
DM, %	24.76	28.32
OM, % of DM	90.55	93.38
OM Digestibility, %	81.70	62.23
Crude Protein,% of DM	27.18	11.35
Nitrogen		
Total N, % of DM	4.35	1.82
Soluble N		
% of DM	1.71	.79
% of total N	39.22	43.72
NPN		
% of DM	.66	.36
% of total N	15.14	19.82
N:DOM, %	5.9	3.1
Soluble Carbohydrates, % of DM	27.11	16.50
IVDMD[a]	76.40	64.43
Forage DM Available		
kg/Ha	539	1690
kg/100 kg BW	57	179
	·········Year 2·········	
Observations	6	6
DM, %	27.76	24.85
OM, % of DM	95.34	93.38
OM Digestibility, %	87.26	70.60
Crude Protein,% of DM	19.31	13.75
Nitrogen		
Total N, % of DM	3.09	2.20
Soluble N		
% of DM	1.50	0.76
% of total N	48.52	34.22
NPN		
% of DM	0.28	0.37
% of total N	8.89	17.16
N:DOM, %	3.7	3.3
Soluble Carbohydrates, % of DM	30.24	21.43
IVDMD[a]	84.69	80.92
Forage DM Available		
kg/Ha	1143	2329
kg/100 kg BW	116	276

[a] In vitro dry matter digestibility

Table 3. Least-Squares Means for Effect of Meat Meal Supplementation on Forage Intake and Nutrient Digestion and Supply of Steers Grazing Immature and Mature Winter Wheat Pasture[a]

	Immature			Mature		
	Control	Meat Meal	SE	Control	Meat Meal	SE
# of observations	7	8		7	7	
Body Weight, kg	447	458	4.6	513	533	4.9
Intake of Forage OM						
kg	15.0	15.9	1.50	7.1	8.3	.44
g/kg BW	32.2	33.4	3.13	11.4	13.0	.95
Nitrogen Intake, g						
Total	662	736	80.40	177	235	7.1
Supplement	15	30		15	30	
Forage	647	706		162	205	
True Ruminal Digestion, g/kg Intake						
OM	779	821	33.6	549	526	23.0
N	792	796	30.6	435	454	64.6
Ruminal N loss,%	57.4	60.9	4.26	-21.5	-15.7	9.79
Deg. Forage N/kg OMTDR	40.6	42.6	2.43	13.6	14.2	2.40
Bacterial Efficiency	13.4	11.4	1.55	47.4	44.2	13.3
Flow to Small Intestine						
Organic Matter						
grams	4653	4753	204.3	4666	5328	212.1
g/kg OM Intake	332	303	19.4	623	632	37.5
g/kg BW	10.3	10.2	.55	8.9	9.9	.49
Non-Ammonia Nitrogen						
grams	259	270	16.6	219	251	12.81
g/kg N Intake	417	382	4.21	1248	1132	92.8
g/kg DOMI	21.2	19.8	.12	44.4[d]	45.1[e]	.39
g/kg BW	.58	.58	.042	.42	.47	.029
Bacterial N,%	53.7	49.2	5.20	54.3	49.2	4.12
Feed N,%	46.3	50.8	5.20	45.7	50.8	4.12

Table 3. Continued.

	Immature			Mature		
	Control	Meat Meal	SE	Control	Meat Meal	SE
Absorbed from Small Intestine						
Organic Matter						
g/kg OM Intake	156	132	12.3	172[b]	234[c]	36.6
% of Flow	47.8	43.6	2.93	28.6[b]	38.0[c]	3.79
g/kg BW	5.0	4.5	.55	2.4[b]	3.5[c]	.30
Non-Ammonia Nitrogen						
g/kg N Intake	255	233	24.7	73.9	72.1	7.72
% of Flow	63.1	60.8	4.05	58.8[d]	62.5[e]	2.09
g NAN/kg DOMI	13.3	12.3	.90	26.0[d]	28.2[e]	.30
g/kg BW	.38	.36	.048	.24[d]	.29[e]	.020
Flow To Large Intestine, g/d						
OM	2406	2638	159.2	3424	3455	290.5
NAN	90	101	5.43	94	99	6.34
Absorbed from Large Intestine						
Organic Matter						
g/kg OM Intake	43	49	9.2	114	101	24.8
% of Flow	15.2	20.6	2.75	16.9	18.0	3.69
g/kg BW	.9	1.4	.16	2.0	1.8	.41
Non-Ammonia Nitrogen						
g/kg N Intake	62	63	2.0	36	119	2.2
% of Flow	27.9	37.8	4.91	24.2	27.5	3.92
g/kg BW	.05	.08	.010	.06	.06	.011
Ruminal Rate of Passage, %/h						
Particulate	4.2	3.7	.82	4.9	4.5	.30
Liquid	5.0	5.0	1.12	6.6	4.9	1.10

[a] Definitions: OM=organic matter; NAN=Non-ammonia nitrogen; bw=body weight; Deg. N/kg OMTDR=Degraded nitrogen per kg OM truly digested in the rumen; Bacterial Efficiency= g N/kg OMTDR.

[bc] Treatment means within stage of forage maturity differ (P<.05).

[de] Treatment means within stage of forage maturity differ (P<.10).

Table 4. Least Squares-Means for the Effect of Meat Meal Supplementation on Ruminal Fermentation of Steers Grazing Immature and Mature Wheat Pasture

	Immature			Mature		
	Control	Meat Meal	SE	Control	Meat Meal	SE
Observations	7[a]	8		7[a]	8	
pH	5.9	5.7	.18	6.2	6.1	.10
Ammonia, mg/dl	23.5	27.7	4.20	19.5	25.4	3.26
Total VFA,mM	167.1	184.0	12.47	173.4	171.9	15.51
VFA molar proportions, %						
Acetic	54.4	55.4	2.22	63.5	64.0	1.59
Propionic	26.4	25.9	1.93	22.5	21.5	1.04
Isobutyric	.5	.4	.09	.5	.6	.11
Butyric	14.5	13.3	.72	11.0	11.1	.69
Isovaleric	1.7	1.9	.20	1.3	1.4	.15
Valeric	2.6	3.0	.58	1.1	1.3	.13
Acetic:propionic	2.2	2.2	.22	2.9	3.1	.21

[a] One steer was removed from the experiment because of problems associated with the intestinal cannula's

Table 5. Chemical Composition (DM basis) of Wheat Forage Grazed by Heifers During Experiment 2[a]

Item	TRIAL 1	TRIAL 2	
		Period 1	Period 2
OM, %	87.05	97.6	98.6
Nitrogen,%	2.98	3.87	3.38
Soluble N,% of total N	24.4	47.8	48.7
NPN,% of total N	12.8	21.0	23.7
Soluble Carbohydrates,%	23.2	32.7	32.9
IVOMD,%	81.6	84.3	85.2
N:DOM,%	4.2	4.7	4.0
Forage DM Available			
kg/Ha	772	1042	927
kg/100 kg BW	132	111	103

[a] Definitions: IVOMD=In vitro organic matter digestibility of esophageal extrusa; DOM=digestible organic matter

TABLE 6. LEAST-SQUARES MEANS FOR EFFECT OF MEAT MEAL SUPPLEMENTATION ON INTAKE OF FORAGE OM AND N BALANCE OF HEIFERS (TRIAL 1)

Item	Control	Meat Meal	SE	OSL[a]
Observations	4	4		
Weight, kg	193	186	13.8	
Forage OM Intake				
kg	2.90	3.96	.448	.20
g/ kg of body weight	15.3	21.2	2.43	.14
N Intake, g/d				
Total	123	183	16.9	.05
Forage	111	159		
Supplement	12	24		
N Excretion, g/d				
Total	55.9	76.6	6.02	.06
Fecal	20.0	27.0	2.07	.06
Urinary	35.9	49.6	4.67	.09
N Retention				
g/d	67.3	106.7	12.90	.09
% of N intake	54.8	57.1	3.47	.66
% of Absorbed N	65.5	67.1	3.61	.77

[a] Observed Significance Level

TABLE 7. LEAST-SQUARES MEANS FOR EFFECT OF MEAT MEAL SUPPLEMENTATION ON INTAKE OF FORAGE OM AND N BALANCE OF HEIFERS (TRIAL 2)

	CONTROL	MEAT MEAL	SE	OSL[a]
Observations	7[b]	8		
Weight, kg	309	324	16.4	
Forage OM Intake				
kg	4.78	5.79	.584	.28
g/kg of body weight	15.1	17.8	1.07	.13
N Intake, g/d				
Total	213	279	22.6	.24
Forage	195	241		
Supplement	18	36		
N Excretion, g/d				
Total	120	155	18.5	.24
Fecal	48	62	7.6	.35
Urinary	72	93	12.7	.24
N Retention				
g/d	93	124	15.8	.24
% of N intake	44.3	43.0	4.76	.86
% of absorbed N	57.1	54.9	5.01	.69

[a] Observed Significance Level
[b] One heifer was deleted from analysis of data because of problems with her urinary catheter.

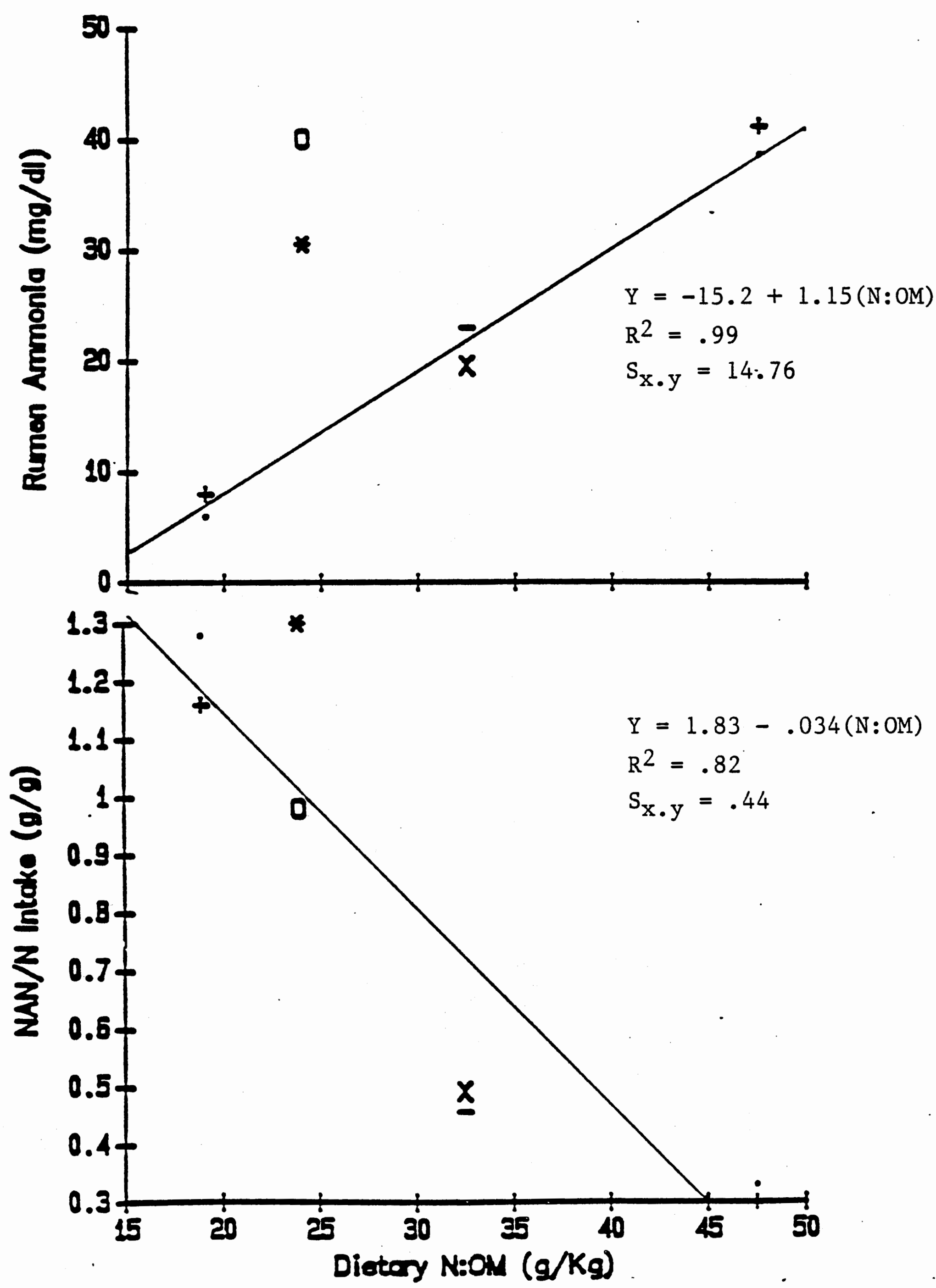

Figure 1. Relationship of rumen ammonia concentration and NAN/N intake flow to the small intestine to forage N:OM concentration. Symbols, for control and meat meal treatments, respectively; 1,+ Immature forage, year 1; x,- Immature forage, year 2; *,0 Mature forage, year 1; .,+ Mature forage, year 2.

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APPENDIX

TABLE 1. COMPUTER PROGRAM FOR CALCULATION OF NUTRIENT FLOW

```
//U14664AA JOB (14664,480-72-
4730),'MARTY',TIME=(0,40),CLASS=3,
// NOTIFY=U14664A,MSGLEVEL=(2,0),MSGCLASS=C
/*PASSWORD ???
/*JOBPARM ROOM=A
/*JOBPARM FORMS=9001
// EXEC SAS,REGION=2000K
//ACA DD DSN=U14664A.WF86P1FL.TXT,DISP=OLD
//BCA DD DSN=U14664A.W86DICR2.TXT,DISP=OLD
//ECA DD DSN=U14664A.WF86RNA.TXT,DISP=OLD
//FCA DD DSN=U14664A.WF86MISC.TXT,DISP=OLD
//CDA DD DSN=U14664A.WF87DCR.TXT,DISP=OLD
//DDA DD DSN=U14664A.WF87ICR.TXT,DISP=OLD
//EDA DD DSN=U14664A.WF87DIN.TXT,DISP=OLD
//FDA DD DSN=U14664A.WF87FCR1.TXT,DISP=OLD
//GDA DD DSN=U14664A.WF87FCR2.TXT,DISP=OLD
//HDA DD DSN=U14664A.WF86FOMN.TXT,DISP=OLD
//IDA DD DSN=U14664A.WF87FOMN.TXT,DISP=OLD
DATA ACA;INFILE ACA;
INPUT TYPE $ 1 ANI 4-5 PDM 6-10 POM 11-15 CRC 16-21 FLCR 22-
31
KNIT 33-36 5 NITFL 38-46;
DATA DUOD; SET ACA;
IF TYPE='D';
DDMFLCR=FLCR;
DOMFLCR=DDMFLCR*POM;
DKNIT=KNIT;
DNITFL=NITFL;
PDMD=PDM;
POMD=POM;
CRCD=CRC;
PROC SORT; BY ANI;
PROC MEANS NOPRINT; BY ANI; VAR DDMFLCR DOMFLCR DKNIT DNITFL
PDMD POMD CRCD;
OUTPUT OUT=DUOD2 MEAN=DDMFLCR DOMFLCR DKNIT DNITFL
PDMD POMD CRCD;
DATA ILEAL; SET ACA;
IF TYPE='I' ;
IDMFLCR=FLCR;
IOMFLCR=IDMFLCR*POM;
IKNIT=KNIT;
INITFL=NITFL;
PDMI=PDM;
POMI=POM;
CRCI=CRC;
```

```
PROC SORT; BY ANI;
PROC MEANS NOPRINT; BY ANI;
VAR IDMFLCR IOMFLCR IKNIT INITFL PDMI POMI;
OUTPUT OUT=ILEAL2 MEAN =IDMFLCR IOMFLCR IKNIT INITFL PDMI
POMI;
DATA FLOW; MERGE DUOD2 ILEAL2;
DATA GOOD1; SET FLOWS; KEEP ANI PERIOD
DDMFLCR IDMFLCR DOMFLCR IOMFLCR
PERIOD =1;
PROC SORT; BY PERIOD ANI;
COMMENT
CHROMIUM DATA OF DOUD AND ILEAL NUTRIENT FLOWS FOR PERIOD 2;
DATA BCA; INFILE BCA;
INPUT ANI 1-3 SAMPLE 4 XBLE 5-9 3 WET 11-15 3 DRY 17-21 3
ASH 23-27 3 CR 30-32 2 CRC 36-41;
DATA DUODCR2; SET BCA;
IF SAMPLE=1;
PDM=((DRY-XBLE)/(WET-XBLE));
POM=((DRY-ASH)/(DRY-XBLE));
DDMFLCR=5445/CRC;
DOMFLCR=DDMFLCR*POM;
PROC SORT; BY ANI;
PROC MEANS NOPRINT; BY ANI;
VAR PDM POM DDMFLCR DOMFLCR;
OUTPUT OUT=DCR2MEAN MEAN=PDM POM DDMFLCR DOMFLCR;
DATA ILEALCR2; SET BCA;
IF SAMPLE=2;
PDMI=((DRY-XBLE)/(WET-XBLE));
POMI=((DRY-ASH)/(DRY-XBLE));
IDMFLCR=5445/CRC;
IOMFLCR=IDMFLCR*POMI;
PROC SORT; BY ANI;
PROC MEANS NOPRINT; BY ANI;
VAR PDMI POMI IDMFLCR IOMFLCR;
OUTPUT OUT=ICR2MEAN MEAN=PDMI POMI IDMFLCR IOMFLCR;
DATA FLOWP2CR;
 MERGE DCR2MEAN ICR2MEAN; BY ANI;
DATA GOOD2; SET FLOWP2; KEEP ANI PERIOD
DDMFLCR IDMFLCR DOMFLCR IOMFLCR
PERIOD =2;
PROC SORT; BY PERIOD ANI;
DATA GOODFLOW; SET GOOD1 GOOD2;
PROC SORT; BY PERIOD ANI;
DATA ECA; INFILE ECA;
INPUT ANI 1-3 PERIOD 5 BRNA 7-12 BNIT 15-19 DRNA 21-26 DNIT
29-33
DNH3N 35-39 KBACNFL 41-47;
PROC SORT; BY PERIOD ANI;
DATA MARTY; MERGE GOODFLOW ECA;
BY PERIOD ANI;
DATA FCA; INFILE FCA;
INPUT ANI 1-3 PERIOD 5 WT 7-10 INIT 13-17 INH3 19-23
DMD 25-29 OMD 31-35 FO 37-41;
FO=FO/2.2;
```

```
IF TRT=1 THEN FO=FO-.118;
IF TRT=2 THEN FO=FO-.257;
INTCR=FO/(1-DMD)*1000;
OMINTCR=FO/(1-OMD)*1000;
PROC SORT; BY PERIOD ANI;
DATA FINAL; MERGE MARTY FCA;
BY PERIOD ANI;
IF ANI=40 THEN TRT=2;
IF ANI=41 THEN TRT=1;
IF ANI=42 THEN TRT=2;
IF ANI=43 THEN TRT=1;
IF ANI=44 THEN TRT=2;
IF ANI=45 THEN TRT=1;
IF ANI=46 THEN TRT=2;
IF ANI=47 THEN TRT=1;
PROC SORT; BY PERIOD ANI TRT;
DATA FINAL2; SET FINAL;
DATA FOMN; INFILE HDA;
INPUT ANI 5-6 PERIOD 15 YEAR 24 FOMFL 33-36 FNIT 42-45;
PROC SORT; BY PERIOD ANI;
PROC PRINT;
DATA FINAL1; MERGE FINAL2 FOMN;
BY PERIOD ANI;
WT=WT/2.2;
MBW=WT**.75;
DNITFLCR=DDMFLCR*(DNIT/100);
DNANFLCR=DDMFLCR*((DNIT-DNH3N)/100);
DNFLCR=DDMFLCR*((DNIT)/100);
INANFLCR=IDMFLCR*((INIT-INH3)/100);
IF PERIOD =1 THEN DO;
NINTCR=(INTCR*.04395);
NINT=NINTCR;
END;
IF PERIOD =2 THEN DO;
NINTCR=(INTCR*.0186);
NINT=NINTCR;
END;
IF TRT=1 THEN NINTCR=NINTCR+12;
IF TRT=2 THEN NINTCR=NINTCR+22.5;
BACNFLCR=DNANFLCR*KBACNFL;
XX=BNIT/100;
XXX=BACNFLCR/XX;
BOMFLCR=XXX*.80;
OMINT=OMINTCR;
NINT=NINTCR;
OMINTBW=OMINT/WT;
ABDMSICR=DDMFLCR-IDMFLCR;
ABOMSICR=DOMFLCR-IOMFLCR;
ANANSICR=DNANFLCR-INANFLCR;
KAOMSICR=ABOMSICR/OMINTCR;
KANANSIC=ANANSICR/OMINTCR;
ARDMDCR=(INTCR-DDMFLCR)/INTCR;
AROMDCR=(OMINTCR-DOMFLCR)/OMINTCR;
ARNITDCR=(NINTCR-DNITFLCR)/NINTCR;
```

```
TROMDCR=(OMINTCR-(DOMFLCR-BOMFLCR))/OMINTCR;
TRNDCR=(NINTCR-(DNANFLCR-BACNFLCR))/NINTCR;
KNANAOMC=ANANSICR/OMINTCR;
KNANANIC=ANANSICR/NINTCR;
KNANAFC=ANANSICR/DNANFLCR;
KBACNFLC=BACNFLCR/DNANFLCR;
WFBPNANC=DNANFLCR-BACNFLCR;
MICEFFCR=BACNFLCR/(OMINTCR-DOMFLCR);
WTM=WT*1;
KOMINTCR=(OMINTCR/1000)/WTM;
KNINTCR=(NINTCR/1000)/WTM;
KNANFLCR=(DNANFLCR/NINTCR);
RPECR=(ANANSICR*23.8)/((OMINTCR-IOMFLCR)*20);
XNANFICR=(DNANFLCR/NINTCR)*100;
KBACNFL=(BACNFLCR/NINTCR)*100;
KBPNFL=(WFBPNANC/NINTCR)*100;
KNOMCR=ANANSICR/(OMINTCR-IOMFLCR);
DNFMBWCR=DNANFLCR/MBW;
KOMINTBW=OMINTCR/WTM;
KNINTBW=NINTCR/WTM;
KTROMDBW=(TROMDCR*OMINTCR)/WTM;
KAOMDBW=(AROMDCR*OMINTCR)/WTM;
KTNDBW=(TRNDCR*NINTCR)/WTM;
KANDBW=(ARNITDCR*NINTCR)/WTM;
KDOMFLBW=DOMFLCR/WTM;
KNANFLBW=DNANFLCR/WTM;
KBACNFL=BACNFLCR/DNANFLCR;
KBPNFL=WFBPNANC/DNANFLCR;
KAOMSIBW=ABOMSICR/WTM;
KANSIBW=ANANSICR/WTM;
KIOMFL=DOMFLCR/OMINTCR;
KINANFL=DNANFLCR/NINTCR;
KIOMASI=ABOMSICR/OMINTCR;
KINANSI=ANANSICR/NINTCR;
PERATIO=ANANSICR/(OMINTCR*OMD);
KAOMSIFL=ABOMSICR/DOMFLCR;
KANSIFL=ANANSICR/DNANFLCR;
KRNDIS=(NINTCR-DNFLCR)/NINTCR;
IOMDIS=IOMFLCR-(FOMFL*1000);
KIOMDFL=IOMDIS/IOMFLCR;
KIOMDINT=IOMDIS/OMINTCR;
KIOMDBW=IOMDIS/WTM;
INITDIS=INANFLCR-((FOMFL*1000)*(FNIT/100));
KINDISFL=INITDIS/INANFLCR;
KINDINT=INITDIS/NINTCR;
KINDISBW=INITDIS/WTM;
GDNTROMD=(NINT-(DNANFLCR-BACNFLCR))/(OMINTCR*OMD);
RESCAPE=(DNANFLCR*(KBPNFL/100))/NINT;
NANFDOMI=DNANFLCR/(OMINT*OMD);
YEAR=1;
PROC PRINT;
PROC GLM DATA=FINAL1;
CLASSES PERIOD ANI TRT;
MODEL WT OMINT OMINTBW NINT TROMDCR TRNDCR KRNDIS GDNTROMD
```

```
DOMFLCR KIOMFL KDOMFLBW DNANFLCR KINANFL KNANFLBW KBACNFL
KBPNFL
KAOMSICR KAOMSIFL KAOMSIBW KINANSI KANSIFL KANSIBW PERATIO
IOMFLCR INANFLCR KIOMDINT KIOMDFL KIOMDBW KINDINT KINDISFL
KINDISBW
RESCAPE NANFDOMI OMD
=TRT ANI(TRT) PERIOD TRT*PERIOD;
TEST H=TRT E=ANI(TRT)/HTYPE=1 ETYPE=1;
LSMEANS TRT TRT*PERIOD/STDERR E=ANI(TRT) ETYPE=1;
LSMEANS PERIOD /STDERR;
DATA FCR; INFILE FDA;
INPUT ANI 1-3 PERIOD 6 XBLE 8-12 3 WET 14-18 3 DRY 20-24 3
ASH 26-30 3 DIL 32-35 3 CR 37-39 2;
CRCDM=(CR*DIL)/(DRY-XBLE);
CRCOM=(CR*DIL)/(DRY-ASH);
PERIOD=1;
PROC SORT; BY ANI PERIOD;
PROC PRINT;
DATA FCR; SET FCR;
PROC MEANS NOPRINT; BY ANI PERIOD; VAR CRCDM CRCOM;
OUTPUT OUT=P1FMEAN MEAN=CRCDM CRCOM;
DATA GCR; INFILE GDA;
INPUT ANI 1-3 PERIOD 6 XBLE 8-12 3 WET 14-18 3 DRY 20-24 3
ASH 26-30 3 DIL 31-35 3 CR 36-38 2;
CRCDM=(CR*DIL)/(DRY-XBLE);
CRCOM=(CR*DIL)/(DRY-ASH);
PERIOD =2;
PROC SORT; BY ANI PERIOD;
PROC MEANS NOPRINT; BY ANI PERIOD; VAR CRCDM CRCOM;
OUTPUT OUT=P2FMEAN MEAN=CRCDM CRCOM;
PROC PRINT;
DATA FOUT; SET P1FMEAN P2FMEAN;
IF PERIOD =1 THEN DO;
FDMOUT=5.755/CRCDM;
FOMOUT=5.755/CRCOM;
FDMOUT=FDMOUT-0.114;
FOMOUT=FOMOUT-0.0114;END;
IF PERIOD=2 THEN DO;
FDMOUT=2.878/CRCDM;
FOMOUT=2.878/CRCOM;
FDMOUT=FDMOUT-0.211;
FOMOUT=FOMOUT-0.0211;END;
DATA DCR; INFILE CDA;
INPUT ANI 1-3 PERIOD 5 XBLE 7-11 3 WET 13-17 3 DRY 19-23 3
ASH 25-29 3 DIL 31-34 3 CR 36-38 2;
DPDM=((DRY-XBLE)/(WET-XBLE));
DPOM=((DRY-XBLE)-(ASH-XBLE))/(DRY-XBLE);
DCRC=(CR*DIL)/(DRY-XBLE);
PROC SORT; BY PERIOD ANI;
PROC PRINT;
DATA DCR; SET DCR;
PROC MEANS NOPRINT; BY PERIOD ANI; VAR DPDM DPOM DCRC;
OUTPUT OUT = DCR MEAN=DPDM DPOM DCRC;
DATA ICR; INFILE DDA;
```

```
INPUT ANI 1-3 PERIOD 5 XBLE 7-11 3 WET 13-17 3 DRY 19-23 3
ASH 25-29 3 DIL 31-34 3 CR 36-38 2;
IPDM=((DRY-XBLE)/(WET-XBLE));
IPOM=((DRY-XBLE)-(ASH-XBLE))/(DRY-XBLE);
ICRC=(CR*DIL)/(DRY-XBLE);
PROC SORT; BY PERIOD ANI;
DATA ICR; SET ICR;
PROC MEANS NOPRINT; BY PERIOD ANI; VAR IPDM IPOM ICRC;
OUTPUT OUT = ICR MEAN=IPDM IPOM ICRC;
INPUT ANI 1-3 PERIOD 5 DNIT 8-10 2 DNH3 13-15 3 KBACN 17-20
4
INAN 23-25 2 DMD 27-33 OMD 35-41 WT 43-46 BNIT 48-52;
DNAN=DNIT-DNH3;
WT=WT/2.2;
IF ANI = 40 THEN TRT =2;
IF ANI = 41 THEN TRT =1;
IF ANI = 42 THEN TRT =2;
IF ANI = 43 THEN TRT =1;
IF ANI = 44 THEN TRT =2;
IF ANI = 45 THEN TRT =1;
IF ANI = 46 THEN TRT =2;
IF ANI = 47 THEN TRT =1;
PROC SORT; BY PERIOD ANI;
DATA FLOW; MERGE FLMARKER DIN; BY PERIOD ANI;
IF PERIOD = 1 THEN CRDOSE = 5.755;
IF PERIOD = 2 THEN CRDOSE = 2.877;
DATA FINALX; MERGE FLOW FOUT; BY PERIOD ANI;
DATA FOMN2; INFILE IDA;
INPUT ANI 5-6 PERIOD 15 YEAR 24 FOMOUT 33-36 FNIT 42-45;
PROC SORT; BY PERIOD ANI;
DATA FINAL; MERGE FINALX FOMN2;
BY PERIOD ANI;
DMINT=FDMOUT/(1-DMD)*1000;
OMINT=FOMOUT/(1-OMD)*1000;
IF PERIOD=1 THEN NINT=DMINT*.0309;
IF PERIOD=2 THEN NINT=DMINT*.0220;
NIN=NINT;
IF TRT=1 THEN NINT=NINT+14;
IF TRT=2 THEN NINT=NINT+45;
DDMFLCR=CRDOSE/DCRC*1000;
DOMFLCR=DDMFLCR*DPDM;
DNITFLCR=DDMFLCR*(DNIT/100);
DNANFLCR=DDMFLCR*(DNAN/100);
BACNFLCR=DNANFLCR*KBACN;
BOMFLCR=(BACNFLCR/BNIT)*.80;
KOMFLCR=DOMFLCR/OMINT;
KNANFLCR=DNANFLCR/NINT;
AROMDCR=(OMINT-DOMFLCR)/OMINT;
ARNITDCR=(NINT-DNITFLCR)/NINT;
TROMDCR=(OMINT-(DOMFLCR-BOMFLCR))/OMINT;
TRNDCR=(NINT-(DNANFLCR-BACNFLCR))/NINT;
IDMFLCR=CRDOSE/ICRC*1000;
IOMFLCR=IDMFLCR*IPDM;
INANFLCR=IDMFLCR*(INAN/100);
```

```
DDMABSCR=DDMFLCR-IDMFLCR;
DOMABSCR=DOMFLCR-IOMFLCR;
DNANABCR=DNANFLCR-INANFLCR;
KOMINTBW=OMINT/WT;
DOMINT=OMINT*OMD;
OMINTBW=DOMINT/WT;
KNINTBW=NINT/WT;
KAOMDBW=(OMINT-DOMFLCR)/WT;
KANDBW=(NINT-DNITFLCR)/WT;
KTROMDBW=(OMINT-(DOMFLCR-BOMFLCR))/WT;
KTNDBW=(NINT-(DNANFLCR-BACNFLCR))/WT;
KDOMFLBW=DOMFLCR/WT;
KNANFLBW=DNANFLCR/WT;
KBACNFL=BACNFLCR/DNANFLCR;
KBPNFL=1-KBACNFL;
KAOMSIBW=DOMABSCR/WT;
KANSIBW=DNANABCR/WT;
RPECR=(DNANABCR*23.8)/((OMINT-IOMFLCR)*20);
KIOMFL=DOMFLCR/OMINT;
KINANFL=DNANFLCR/NINT;
KAOMSICR=DOMABSCR/OMINT;
KINANSI=DNANABCR/NINT;
PERATIO=DNANABCR/(OMINT*OMD);
KAOMSIFL=DOMABSCR/DOMFLCR;
KANSIFL=DNANABCR/DNANFLCR;
KRNDIS=(NINT-DNANFLCR)/NINT;
IOMDIS=IOMFLCR-(FOMOUT*1000);
KIOMDFL=IOMDIS/IOMFLCR;
KIOMDINT=IOMDIS/OMINT;
KIOMDBW=IOMDIS/WT;
INITDIS=INANFLCR-(FOMOUT*1000*(FNIT/100));
KINDISFL=INITDIS/INANFLCR;
KINDINT=INITDIS/NINT;
KINDISBW=INITDIS/WT;
GDNTROMD=(NIN-(DNANFLCR-BACNFLCR))/(OMINT*OMD);
RESCAPE=(DNANFLCR*KBPNFL)/NINT;
NANFDOMI=DNANFLCR/(OMINT*OMD);
IF ANI=45 THEN DELETE;
YEAR=2;
PROC PRINT;
PROC GLM DATA=FINAL;
CLASSES PERIOD ANI TRT;
MODEL WT OMINT OMINTBW NINT TROMDCR TRNDCR KRNDIS GDNTROMD
DOMFLCR KIOMFL KDOMFLBW DNANFLCR KINANFL KNANFLBW KBACNFL
KBPNFL
KAOMSICR KAOMSIFL KAOMSIBW KINANSI KANSIFL KANSIBW PERATIO
IOMFLCR INANFLCR KIOMDINT KIOMDFL KIOMDBW KINDINT KINDISFL
KINDISBW
RESCAPE NANFDOMI=
TRT ANI(TRT) PERIOD TRT*PERIOD;
TEST H=TRT E=ANI(TRT)/HTYPE=1 ETYPE=1;
LSMEANS TRT TRT*PERIOD/STDERR E=ANI(TRT) ETYPE=1;
LSMEANS PERIOD/STDERR;
DATA POOLED; SET FINAL1 FINAL; KEEP YEAR PERIOD ANI TRT OMD
```

```
WT OMINT OMINTBW NINT TROMDCR TRNDCR KRNDIS GDNTROMD
DOMFLCR KIOMFL KDOMFLBW DNANFLCR KINANFL KNANFLBW KBACNFL
KBPNFL
KAOMSICR KAOMSIFL KAOMSIBW KINANSI KANSIFL KANSIBW PERATIO
IOMFLCR INANFLCR KIOMDINT KIOMDFL KIOMDBW KINDINT KINDISFL
KINDISBW
RESCAPE NANFDOMI;
PROC SORT; BY YEAR PERIOD ANI;
PROC SORT; BY PERIOD;
PROC PRINT;
PROC GLM DATA=POOLED; BY PERIOD;
CLASSES TRT YEAR ANI;
MODEL WT OMINT OMINTBW NINT TROMDCR TRNDCR KRNDIS GDNTROMD
DOMFLCR KIOMFL KDOMFLBW DNANFLCR KINANFL KNANFLBW KBACNFL
KBPNFL
KAOMSICR KAOMSIFL KAOMSIBW KINANSI KANSIFL KANSIBW PERATIO
RESCAPE
IOMFLCR INANFLCR KIOMDINT KIOMDFL KIOMDBW KINDINT KINDISFL
KINDISBW
NANFDOMI=
TRT ANI(TRT) YEAR TRT*YEAR;
TEST H=TRT E=ANI(TRT)/ETYPE=1 HTYPE=1;
LSMEANS TRT/STDERR ETYPE=1;
LSMEANS YEAR TRT*YEAR/STDERR;
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NOMENCLATURE

ANI	Animal Identification
PDM	Percent Dry Matter
POM	Percent Organic Matter
CRC	Chromium Concentration (PPM)
FLCR	Dry Matter Flow to the Duodenum (g/d)
KNIT	Percent Nitrogen
NITFL	Nitrogen Flow To Duodenum (g/d)
DDMFLCR	Dry Matter Flow to the Duodenum (g/d)
DOMFLCR	Organic Matter Flow to the Duodenum (g/d)
DKNIT	Percent Nitrogen Flow of Organic Matter Flow to the Duodenum
DNITFL	Nitrogen Flow to the Duodenum (g/d)
PDMD	Percent Dry Matter
POMD	Percent Organic Matter
CRCD	Chromium Concentration in Duodenal Samples (PPM)
IDMFLCR	Dry Matter Flow to the ileum (g/d)
IOMFLCR	Organic Matter Flow to the Ileum (g/d)
IKNIT	Percent Nitrogen of Dry Matter Flow to the ileum
INITFL	Nitrogen Flow to the Ileum (g/d)
PDMI	Residual Dry Matter of Ileal Samples (%)
POMI	Percent Organic Matter of Ileal Samples (%)
CRCI	Chromium Concentration in Ileal Samples (PPM)
BRNA	Nucleic acid Concentration in Isolated Bacteria
BNIT	Nitrogen Concentration of Isolated Bacteria (%)
DRNA	Nucleic Acid Concentration in Duodenal Samples
DNIT	Nitrogen Concentration in Duodenal Samples (%)
DNH3N	Ammonia Nitrogen Concentration in Duodenal Samples (%)
KBACNFL	Percent Bacterial Nitrogen of Total Nitrogen Flowing to the Small Intestine
INIT	Nitrogen Concentration of Flow to Ileum (%)
INH3	Ammonia Nitrogen Concentration of Flow to Ileum
FO	Fecal Dry Matter Output (kg/d)
INTCR	Dry Matter Intake (g/d)
OMINTCR	Organic Matter Intake (g/d)
WT	Weight (kg)
MBW	Metabolic Body Weight (kg)
DNITFLCR	Nitrogen Flow to the Small Intestine (g/d)
DNANFLCR	Non-Ammonia Nitrogen Flow to the Duodenum (g/d)
DNFLCR	Nitrogen Flow to the Small Intestine (g/d)
INANFLCR	Non-Ammonia Nitrogen Flow to the Ileum (g/d)
NINTCR	Nitrogen Intake (g/d)
BACNFLCR	Bacterial Nitrogen Flow to the Duodenum (g/d)
OMINTBW	Organic Matter Intake as a percent of Body Weight

ABDMSICR	Absorption of Dry Matter from the Small intestine (g/d)
ABOMSICR	Absorption of Organic Matter from the small Intestine (g/d)
ANANSICR	Absorption of Non-Ammonia Nitrogen from the Small Intestine (g/d)
KAOMSICR	Absorption of Organic Matter from the Small Intestine as percent of Organic Matter Intake
KANANSIC	Absorption of Non-Ammonia Nitrogen from the Small Intestine as percent of Nitrogen Intake.
ARDMDCR	Apparent Rumen Dry Matter Digestion (% of Intake)
AROMDCR	Apparent Rumen Organic Matter Digestion (%)
ARNITDCR	Apparent Rumen Nitrogen Digestion (%)
TROMDCR	True Rumen Organic Matter Digestion (%)
TRNDCR	True Rumen Nitrogen Digestion (5)
KNANAOMC	Absorption of Non-Ammonia Nitrogen as a Percent of Organic Matter Intake
KNANANIC	Absorption of Non-Ammonia Nitrogen as a Percent of Nitrogen Intake
KNANAFC	Absorption of Non-Ammonia Nitrogen as a percent of Non-Ammonia Nitrogen Flow to the Duodenum
KBACNFLC	Percent Bacterial Nitrogen Flow of Nitrogen Flowing to the Duodenum
WFBPNANC	Feed NAN Flow to the Duodenum (g/d)
MICEFFCR	Microbial Efficiency (g Bacterial N/kg OM Fermented in the Rumen
WTM	Body Weight (kg)
KOMINTCR	OM Intake as Percent of Body Weight
KNINTCR	Nitrogen Intake as Percent of Body Weight
KNANFLCR	Non-Ammonia Nitrogen Flow to Duodenum (g/g of Nitrogen Intake)
RPECR	Ratio of Protein energy Absorbed from small Intestine as Percent of DOMI
XNANFICR	Non-Ammonia Nitrogen Flow to Duodenum as Percent of Nitrogen Intake
KBACNFL	Bacterial N Flow to Duodenum (% of N Flow)
KBPNFL	Feed N Flow to Duodenum (% of N Flow)
DNFMBWCR	Non-Ammonia Nitrogen Flow per kg Body Weight
KTROMDBW	True Rumen Organic Matter Digestion (% of Body Weight)
KAOMDBW	Apparent Rumen Organic Matter Digestion (% of Body Weight)
KTNDBW	True Rumen Nitrogen Digestion (% of Body Weight)
KANDBW	Apparent Rumen Nitrogen Digestion (% of Body Weight)
KDOMFLBW	Organic Matter Flow to Duodenum (% of Body Weight)
KNANFLBW	Non-Ammonia Nitrogen Flow to Duodenum (% of Body Weight)
KAOMSIBW	Organic Matter Absorption from Small Intestine (% of Body Weight)
KANSIBW	Non-Ammonia Nitrogen Absorption from Small Intestine (% of Body Weight)
KIOMFL	Organic Matter Flow to Duodenum as a Percent of Organic Matter Intake

KINANFL	Non-Ammonia Nitrogen Flow to Duodenum as a Percent of Nitrogen Intake
KIOMASI	Organic Matter Absorption from the Small Intestine (% of Organic Matter Intake)
KINANSI	Non-Ammonia Nitrogen Absorption (% of Non-Ammonia Nitrogen Intake
PERATIO	Non-Ammonia Nitrogen Absorption from the Small Intestine per kg Digestible Organic Matter Intake
KAOMSIFL	Absorption of Organic Matter from Small Intestine as a percent of Organic Matter Flow to Duodenum
KANSIFL	Absorption of Non-Ammonia Nitrogen from Small Intestine as a percent of Flow to Duodenum
KRNDIS	Nitrogen Disappearance between Ingestion and Duodenum
KIOMDFL	Organic Matter Digestion in Large Intestine as a Percent of Flow to Large Intestine
KIOMDINT	Organic Matter Digestion in Large Intestine as a percent of Organic Matter Intake
KIOMDBW	Organic Matter Digestion in the Large Intestine as a percent of Body Weight
INITDIS	Nitrogen Digestion in the Large Intestine (g/d)
KINDISFL	Nitrogen Digestion in the Large Intestine as a Percent of FLow to the Large Intestine
KINDINT	Nitrogen Digestion in the Large Intestine as a Percent of Nitrogen Intake
KINDISBW	Nitrogen Digestion in the Large Intestine per kg of Body Weight
GDNTROMD	Grams of Protein Nitrogen Degraded in the Rumen Per kg of Organic Matter Truly Fermented
CRCDM	Chromium Concentration (PPM) DM-BASIS
CRCOM	Chromium Concentration (PPM) OM-BASIS
XBLE	Beaker Weight (g)
WET	Beaker + Sample Weight (g)
DRY	Beaker + Dry Sample Weight (g)
ASH	Beaker + Ashed Sample Weight (g)
DIL	Dilution Factor
FDMOUT	Fecal Dry Matter Output (kg)
FOMOUT	Fecal Organic Matter Output (kg)
DPDM	Percent Dry Matter of Duodenal Sample
DPOM	Percent Organic Matter of Duodenal Sample
DCRC	Chromium Concentration of Duodenal Sample (PPM)
IPDM	Percent Dry Matter of Ileal Sample
IPOM	Percent Organic Matter of Ileal Sample
ICRC	Chromium Concentration of Ileal Sample (PPM)

Table 2. Nucleic acid (RNA basis) and N concentration in isolated bacteria samples and duodenal samples for meat meal trials.

	Bacteria		Duodenal	
	Nucleic Acid,%	N,%	Nucleic Acid,%	N,%
Immature Wheat Forage				
Year 1				
Control	7.9	7.6	3.5	5.1
Meat meal	8.0	7.5	3.4	5.2
Year 2				
Control	10.8	5.4	3.2	4.8
Meat meal	8.0	4.0	3.0	5.1
Mature Wheat Forage				
Year 1				
Control	8.0	7.7	3.0	4.1
Meat meal	8.0	7.7	2.9	4.2
Year 2				
Control	13.2	6.4	3.0	4.4
Meat meal	14.4	6.5	2.8	4.5

VITA

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Doctor of Philosophy

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