THE EFFECT OF PROTEIN SUPPLEMENTATION ON PERFORMANCE OF GROWING RUMINANTS GRAZING WHEAT PASTURE

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Bachelor of Science

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Canyon, Texas

1988

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1990

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PERFORMANCE OF GROWING RUMINANTS

GRAZING WHEAT PASTURE

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ACKNOWLEDGEMENTS

I wish to express sincere appreciation and thanks to Dr. Gerald Horn for his invaluable guidance, advisement and friendship throughout my graduate program here at OSU. Without his help and encouragement this manuscript might not have gotten done. Many thanks to Dr. McCollum and Dr. Wagner for serving on my committee and encouraging me. A special thanks goes to Dr. Bill Phillips for all the help, advice, service on my committee and friendship. I could not have done my research at Fort Reno without him.

To the graduate students I met here - Greg Mclean, Kathy Ovenell, Paula Dubeski, Laurie O'Neill, Ward Stutz and the many others, thanks for your caring, good humor and support. I have learned more from you than books alone can teach.

This research could not have been completed without the help of some special people. Thanks to Ken Poling for assistance with animals and to Donna Perry for teaching and assisting me with lab work and for their friendship. A special thanks to Jeff Schatz for his encouragement and help and for having answers to my questions. Also, special thanks to Carolyn and Judy for being my friends and for their encouragement and help whenever I needed it.

I would like to especially thank my family and my

parents, Geral and Jamie Smith, for all their love and support and for encouraging me to pursue my goals, no matter what they have been. Lastly and most important; a special thanks and much love goes to my husband, Thad Murphy, for his love, good humor, much encouragement and putting up with me as I have finished.

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CHAPTER I

INTRODUCTION

Each year millions of stocker cattle are grazed on wheat pasture in the southern Great Plains region, about 1.5 million in Oklahoma alone. Rate of weight gain is a key factor in the profitability of stocker cattle enterprises. Relatively small increases in daily gain, as achieved by improved management or use of supplements, will frequently increase profits by $25 to $30 per head. Both quality and quantity of forage affect gains. Weight gains are generally good due to the high quality of wheat forage. It commonly contains 20 to 30% crude protein (dry matter basis), but fluctuations in amount of available forage, both within and among years, and snow and(or) ice cover can affect gains.

Supplementation of cattle can have several advantages (Wagner et al., 1984) which include 1) increased daily gain, 2) enhanced cattle management, 3) increased stocking rates or carrying capacity, 4) inclusion of feed additives such as poloxalene and ionophores to reduce health problems and increase gains and 5) improvement in overall nutrient supply.

Typically, weight gains are improved about .1 to .15 kg/day when 2.27 to 4.83 kg/hd/day high energy grain based

supplements are fed (Wagner et al., 1984). But, the efficiency of supplement use is often quite low, approximately 9.4 to 10.3 kg of grain per kg of increased weight gain (Elder, 1967 and Gulbransen, 1976).

As stated previously, wheat forage will commonly contain 25 to 30% crude protein. However, it also contains large amounts of soluble nitrogen (N; 30 to 45% of total N) and soluble non-protein N (NPN; 17 to 34% of total N). Beever et al. (1976) observed a significant negative relationship ($r = -.98$, $P<.001$) between the amount of N flowing into the small intestine and solubility of N in perennial ryegrass.

Studies by Vogel (1988) have shown that the N of immature and mature wheat forage exist kinetically as two distinct pools with different rates of in situ ruminal disappearance. Approximately 50 to 75% of the total wheat forage N was found in a "fast" pool which dissapeared at rates of 16 to 19%/hour. Because some of the rapidly degraded wheat forage N is lost as ammonia-N and is not incorporated into microbial protein, performance of rapidly growing cattle on wheat pasture may be limited by flow of inadequate amounts of protein to the small intestine (Beever, 1984; Vogel et al., 1987). The primary objective of this study was to determine the effect of feeding additional supplemental protein of low ruminal degradability on weight gains of stocker cattle grazing wheat pasture and

forage intake and N balance of lambs fed harvested wheat forage in metabolism stalls.

CHAPTER II

REVIEW OF LITERATURE

Composition and Quality of Wheat Pasture

Small grain cereal crops (i.e., wheat, oats and barley) provide grazing animals with a high quality forage during the immature, vegetative stage of growth. As with small grain cereal crops, fresh immature temperate forages possess intrinsic characteristics that can influence nitrogen (N) digestion in ways that other feedstuffs are not capable of (MacRae and Ulyatt, 1974). These intrinsic factors are a decreased dry matter (DM) content, higher N content and a higher N to carbohydrate ratio than in other forages. A large proportion of the total N is in the soluble form and is readily released into the rumen.

Wheat and other small grain forages are generally characterized by high crude protein (CP) and DM digestibility values and low dry matter content. Wheat forage will commonly contain 25 to 30% CP during the fall, winter and early spring when it is utilized for grazing. Chemical characteristics of wheat pasture over a 4 year period were reported by Stewart et al (1981). Dry matter contents ranged from 20 to 45% and crude protein concentrations were greater than 20% (DM basis). Johnson et

al. (1974) reported CP values of wheat forage of 25 to 31% of DM and Horn (1984) reported in vitro dry matter digestibility (IVDMD) values of 70 to 80%.

The CP content in forages is sometimes classified as either true protein or non-protein nitrogen (NPN). Fresh forages often contain large quantities of NPN and soluble N. In wheat pasture, large amounts of soluble N and soluble NPN are present in the CP fraction (Johnson et al., 1974; Horn et al., 1977). The soluble N and NPN content of forages can have a great impact on the amount of N reaching the small intestine. Beever et al. (1976) found a significant negative relationship ($r = -.98$; $P<.001$) between the amount of N flowing to the small intestine and the solubility of N of perennial ryegrass conserved by different methods. Vogel (1988) observed significant correlations between the size of a highly soluble rapidly disappearing N pool in the rumen and soluble N ($r = .69$; $P<.05$) and NPN ($r = .67$; $P<.05$) content of wheat forage.

Digestion and Utilization of Nitrogen from High Quality Forages

Extent of Ruminal Nitrogen Digestion

In ruminants, site of digestion is often a major factor determining extent of nutrient digestibility and utilization. Increasing the amount of dietary nutrients, particularly protein, made available for digestion and

absorption in the small intestine could increase the overall efficiency of nutrient utilization (Blaxter and Martin, 1962).

Nitrogen is a critical nutrient in the ruminant, since it is an important component of protein. Ruminants cannot use N as a nutrient at the tissue level, but ruminal bacteria can incorporate non-protein nitrogen (NPN) into bacterial protein. These bacteria are subsequently digested by the animal and their protein is used to supply needed amino acids for growth (NRC, 1985).

Rumen microorganisms cause major transformations of dietary nitrogenous compounds. Most forms of NPN are converted almost quantitatively to ammonia. Some of the ammonia (NH_3 and/or NH_4^+) is incorporated into rumen bacteria in the form of amide groups and used for synthesis of amino acids (Smith, 1979). True protein is degraded to a variable extent to peptides, amino acids and ammonia. It is also used to synthesize bacterial crude protein (NRC, 1985; Tamminga, 1979).

Not all of the protein that enters the rumen is broken down. The term "bypass" or "escape" protein refers to that portion of the dietary protein that evades degradation in the rumen. However, estimates of the amount of protein escaping degradation in the reticulo-rumen are extremely variable (NRC, 1985). Most small grains and high-quality forages have protein that is highly degradable while many by-product feeds appear to be relatively resistant to

ruminal degradation. Experimental results, both in vitro and in vivo show varying amounts of degradation of dietary protein. Part of this variation, particularly in vivo, must be attributed to inadequate measuring techniques (Tamminga, 1979).

The extent to which protein is degraded in the rumen depends on several factors: 1) microbial proteolytic activity, 2) microbial access to the protein and 3) rumen turnover (Tamminga, 1979; NRC, 1984; NRC, 1985). Microbial access, due to protein structure and rumen turnover, or retention time appear to have the most effect on whether dietary protein escapes degradation.

Apparent N digestibility estimates for fresh forages are often high. Total tract N digestibility of ryegrass and white clover at three stages of forage maturity exceeded 95% on all diets except for the mid (88%) and late (90%) white clover (Cammell et al., 1983). Corbett et al. (1982) reported that N digestibility of Phalaris, Lucerne and native pasture had digestibility coefficients of 91.5, 95.0 and 75.5, respectively. Although these studies indicate total tract N digestibility is high, few studies have attempted to quantify the extent of ruminal N digestion.

Rate of passage was shown to have a major effect on N digestion. In a study comparing white clover to ryegrass, less nitrogen (as % of N intake) was lost from the stomachs of sheep fed white clover than those fed ryegrass (18.0 vs 26.5, respectively). More protein (49.4 vs 40.0% of N

intake) was found to be available for digestion in the small intestine of the sheep fed white clover as compared to ryegrass. This was due to the lower retention time of clover than ryegrass (6.3 vs 10.4 h, respectively) in the rumen. It was felt that the increased protein available for digestion in the small intestine was due to the quantity and not the quality of amino acids available (the amino acid composition of protein entering the duodenum was similar for both diets; Ulyatt, 1981).

Using a modified dacron bag technique, Anderson et al. (1988) found that 80 to 90% of total protein in bromegrass was potentially digestible in the rumen. Calculated extent of ruminal N degradation was 91.8 and 86.1% for bromegrass during the spring and fall grazing seasons, assuming a passage rate of 5%/h. Ulyatt et al. (1975) reported that ruminal digestion of dietary N was 69.1, 69.7 and 72.5% for sheep fed perennial ryegrass, short rotation ryegrass and white clover, respectively. Beever et al. (1986b) compared perennial ryegrass and white clover at three stages of maturity and found that extent of ruminal N digestion ranged from 64 to 87%, but that differences due to forage species (ryegrass, 74.4; clover, 78.6%) and stage of forage maturity (early, 78.3; mid, 75.2; late 78.6%) were small. However, Hume and Purser (1974) indicated that extent of ruminal N digestion did depend on stage of forage maturity. They reported more N ($P<.05$) was degraded ruminally in sheep consuming immature (73.5%) than mature (43 to 53%)

subterranean clover. Similar results were observed by Zorrilla-Rios et al. (1985) when comparing ruminal digestion of wheat forage at two stages of forage maturity. Ruminal N digestion of wheat forage decreased from 72.2 to 44.4% with increasing forage maturity.

The extensive breakdown of dietary N from fresh forages in the rumen is most likely because of the high quantity of soluble N and NPN and the rapid rates of N digestion. Rate of N degradation affects microbial protein synthesis and flow of feed N to the small intestine. Limited information is available on rate of N disappearance of high quality forages. Vogel (1988) reported that wheat forage N exists kinetically as two distinct N pools. Approximately 50 to 75% of wheat forage N was present in a highly soluble rapidly degrading pool which disappeared at rates of 16 to 19%/h. Beever et al. (1986b) reported that rates of N disappearance of ryegrass and white clover each differed at three stages of forage maturity. Rate of N disappearance was 41.6% faster ($P<.01$) for the white clover (17 vs 12%/h) than ryegrass. Effects due to stage of maturity were noted particularly for the late cut forages. Rate of N disappearance of ryegrass decreased from 13.5%/h for the early and mid cut to 9%/h for the late cut forage. Rates of N disappearance for white clover were 16, 22 and 13%/h respectively for the early, mid and late cut forages. Anderson et al. (1988) found that rate of N disappearance averaged 12.9%/h in situ for bromegrass. They indicated

that within 12 h, greater than 86% of the potentially digestible N had disappeared.

Losses of Nitrogen Prior to the Small Intestine

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

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

An equation was developed (Beever et al., 1986a)

relating non-ammonia N (NAN) flow per unit of N intake (Y) and dietary N content in the forage OM (X) for steers fed white clover and perennial ryegrass. The equation was Y = 1.5074 - .01854X (r^2 = .86). Thus, NAN flow to the small intestine would be less than N intake when forage N was greater than 27.5 g N/kg OM (i.e. 15.3% CP). They also suggested that efficiency of utilization of N in fresh forages was more closely related to forage N content than forage species. Using their equation and assuming that wheat forage contains 4% N and 90% OM, NAN flow to the small intestine would only be 68% of N intake (Vogel, 1988). Andersen (1988) reported a similar value. Hogan and Weston (1970) also developed a similar equation: Y = 1.4304 - .01691X. They concluded that NAN flow would be less than N intake when forage N exceeded 25.5 g N/kg DM (i.e. 15.9% CP). Using a value of 4% N for wheat forage, NAN flow to the small intestine would be 75.4% of N intake (Vogel, 1988). Hogan (1982) related the ratio of N/digestible organic matter (DOM) to the amount of NAN digested in the small intestine of sheep consuming a wide variety of forages. He found that when the N/DOM ratio was greater than 3%, NAN flow to the small intestine was less than N intake. For perspective, Vogel (1988) reported that the N/DOM ratio in wheat forage is approximately 5%.

Because large losses of N are observed prior to the small intestine, it would be assumed that ruminal ammonia concentrations would be high. Numerous studies have

reported ruminal NH_3 concentrations far above the minimal requirements for bacterial growth. Rumen NH_3 concentrations of 43.0 and 19.8 mg/dl for steers consuming immature and mature wheat forage, respectively, were reported by Zorrilla-Rios et al. (1985). Beever et al. (1986a) reported that NH_3 concentrations varied more than 10-fold for steers consuming ryegrass and white clover at three stages of forage maturity. Rumen NH_3 levels for cattle consuming ryegrass were 5.9, 5.9 and 24.2 mg/dl on the early, mid and late forages, respectively. On the white clover the concentrations were 28.3, 37.2 and 59.0 mg/dl, respectively. In each of the studies rumen NH_3 concentrations were above the "minimum" requirement of 5 mg/dl needed for maximum microbial protein production as suggested by Satter and Slyter (1974). These researchers reported that increases in NH_3 concentrations above this level would have no effect on microbial protein production. Therefore, it would appear that excess NH_3 produced during the degradation of forage N above the capacity of rumen microbes to assimilate it into microbial protein would be lost.

Because large losses of ingested N occur prior to the small intestine, Beever (1984) concluded that the supply of NAN to the small intestine may limit performance of rapidly growing cattle grazing high quality forages. MacRae and Ulyatt (1974) reported that 63% of the variation in liveweight gains of sheep grazing ryegrass and white clover pastures was associated with the amount of NAN absorbed from

the small intestine. They also concluded that there was no relationship between liveweight gain and energy absorbed as volatile fatty acids (a measure of "energy status" of the animal). Barry et al. (1982) reached a similar conclusion when they observed that infusion of sodium caseinate (44 g/d) and L-methionine (.5 g/d) increased ($P<.05$) deposition of protein of both wool and body protein tissue in lambs fed perennial ryegrass. They concluded that protein deposition was limited by amino acid absorption from the small intestine. Keeping this in mind, the traditional idea that performance of rapidly growing cattle grazing wheat pasture is not limited by protein supply and(or) a deficiency of specific amino acids in the small intestine may not be valid and is in need of further study.

Effect of Protein Supplementation on Performance of Ruminants Grazing High Quality Forages

Cattle ingesting low quality forages have shown improved weight gains and increased forage intake when fed protein supplements. These improvements may be due in part to an increased protein supply to the animal, particularly in the small intestine (Egan, 1965b; Hennessy et al., 1981; Horn et al., 1982; McCollum and Galyean, 1985; Fernandez-Rivera et al., 1989). If this is true for low quality

forages, is it also true on high quality forages such as wheat pasture?

Proposed Mechanisms for Improvement in Performance

Beever et al. (1987) tried to decrease the amount of forage N degraded in the rumen to improve protein flow to the small intestine. Cattle were fed fresh harvested forage and given either no treatment or monensin (intra-ruminal) at the time of feeding or formaldehyde application to the forage prior to feeding. They concluded that the extensive loss of N from the reticulo-rumen of cattle fed fresh forages can be reduced by the use of agents to reduce protein solubility. The use of formaldehyde may, in some circumstances, increase N supply to the small intestine more through enhancing microbial N synthesis in the rumen than through increasing the passage of undegraded feed N to the small intestine. Monensin had no effect on total flow of NAN to the small intestine.

Several mechanisms for increasing performance of animals when supplemented with protein other than an increase in protein flow to the small intestine have been proposed. First, the supplemental protein could correct an amino acid imbalance. Harper and Benevenga (1978) reported the classical response of an amino acid imbalance is decreased feed intake and rate of gain which can be corrected by supplementation of the limiting amino acid.

Studies of amino acid imbalances with nonruminants have shown marked improvements in nitrogen balance. Pigs fed diets containing high lysine corn retained significantly more ($P<.01$) nitrogen than those fed isonitrogenous diets of normal corn and non-essential N or normal corn (0.902 vs 0.503 and 0.376 g/kg $wt^{\cdot 734}$/day, respectively). Although part of the increased N retention was attributed to a greater ($P<.01$) absorption of the high lysine corn N (82.31 vs 77.07%), the majority of the difference was due to a greater ($P<.01$) retention of the N that was absorbed (49.79 vs 35.29%; Cromwell et al., 1969).

Barry et al. (1982) reported the effects of abomasal infusions of casein and methionine on growing lambs receiving a ryegrass/white clover diet. The level of protein infusion was fixed to increase small intestinal absorption of protein by approximately 40 g/day (control 60 g/day, infused 99 g/day). This was found to be associated with a 25% increase in live weight gain (control 79 g/day, infused 99 g/day) and a 70% increase in total protein deposition (12.6 vs 21.0 g/day, respectively). Consequently, they concluded that protein infusion had the overall effect of increasing the proportion of energy retained as protein from 0.27 to 0.41.

Egan and Moir (1965) and Egan (1965a) conducted studies in which they infused casein or urea into the duodenum of lambs fed a low-protein roughage diet. Of the 10 g of N infused, 7.4 g of casein N and 5.0 g of urea N were

retained. Infusion of casein increased voluntary intake of the low-protein roughage. Infusion of urea caused an increased intake in one trial but had no effect in other trials. Results of these experiments suggested that an increased protein intake (in the form of casein) initiated an improvement in dry matter and digestible energy intake which was related to improved N retention.

Schelling and Hatfield (1968) compared the effects of abomasally infused nitrogen sources on N retention of growing lambs. Lambs were fed a purified diet with urea as the sole N source, either ad libitum or controlled intake, and were then infused with different N sources. Infusion of casein; all essential amino acids; a mixture of arginine, histidine, lysine, phenylalanine and methionine; acid hydrolyzed casein with methionine and tryptophan added; lysine and glutamic acid all increased ($P<.10$) N retention. The infusion of casein increased ($P<.10$) voluntary feed intake about 15%. They concluded that not only was animal growth, as measured by N retention, influenced by amino acid administration, but also voluntary feed intake was influenced by the administration of casein.

Another proposed mechanism, as suggested by MacRae and Lobley (1982), is that additional protein increases the efficiency of metabolizable energy (ME) use. MacRae et al. (1985) observed a 27% increase in efficiency of ME utilization of sheep consuming autumn-harvested grass hay when casein was infused into the abomasum. They suggested

the increased efficiency was due to an increase in NADPH production from gluconeogenic amino acids supplied by the additional protein. On forage based diets where acetate is the primary product of ruminal fermentation, NADPH levels may be inadequate for efficient energy use. As a result, excess acetate is probably lost in some futile cycle. Increasing the supply of NADPH would increase efficiency of ME use by supplying a source of reducing equivalents for fatty acid synthesis (Vogel, 1988). However, Black et al. (1987) using a computer simulation model concluded that increased animal performance with additional protein on forage based diets was not related to increased NADPH production but rather to increased protein absorption which increased ATP utilization for body protein synthesis.

These proposed mechanisms - increased N supply post-ruminally, correction of amino acid imbalance and increased efficiency of ME use - could be responsible for the improved performance of animals fed high quality forages and supplemented with additional protein.

Protein Supplementation on High Quality Forages

There are several reports to support the view that protein supplementation of animals ingesting fresh, high-quality forages may give increased production responses. To consider both energy and protein supplementation of fresh grass, Penning and Treacher (1981) fed lactating ewes

grazing fresh ryegrass either a high energy supplement (barley plus maize starch) or one of three protein supplements (soybean meal, fishmeal or a mixture of the two proteins). Energy supplementation increased total organic matter intake by 23% but there was only a 4% increase in milk yield. The protein supplements increased milk yields by 12, 25 and 24%, respectively. As a result, lambs suckling ewes receiving the fishmeal supplement gained 12% more than lambs of ewes receiving energy supplements and 18% more than lambs of the non-supplemented ewes. Rogers et al. (1980) reported that supplementation with formaldehyde-treated casein of dairy cows consuming a "high quality pasture" (2.8% N) increased milk production by 13% and milk protein by 15%. The increases in milk yield and milk protein were not associated with any increases in forage or total dry matter intake. Therefore, they concluded that milk synthesis was limited by the amount of protein absorbed post-ruminally and that the utilization of the digestible energy of the forage was improved by the protected casein.

Poppi et al. (1988) supplemented lambs grazing perennial ryegrass and white clover with fishmeal, methionine hydroxy analogue (MHA) and protected methionine and lysine. Supplements were supplied twice daily (orally after suspension in water). Fishmeal significantly increased liveweight gain (g/day) but amino acid supplementation of supposedly first limiting amino acid(s) did not. They suggested that substantial benefit may arise

through reducing rumen protein losses and(or) increasing duodenal protein supply of animals grazing high protein content pasture.

In a study by Worrell et al. (1988) steers grazing ryegrass pasture were supplemented with .45 kg/day of mechanically extracted cottonseed meal with and without 150 mg of lasalocid. Although no control, energy-based supplement was fed, supplementation with cottonseed meal resulted in a nonsignificant increase in daily gains of 12.7% (1.42 vs 1.26 kg/day) while inclusion of lasalocid with the cottonseed meal resulted in a 23% increase ($P<.05$) in daily gains compared to the non-supplemented steers (1.55 vs 1.26 kg/day). They suggested that metabolizable protein was limiting gain in the early grazing season.

Grigsby et al. (1987) reported results of a 90 day trial where cattle grazing rye-ryegrass pastures were supplemented with fishmeal, corn or corn plus rumen stable lysine and methionine. They found that daily weight gains (kg/day) were lower ($P<.01$) for calves grazing pasture alone (1.08) or supplemented with fishmeal (1.19) than for calves supplemented with corn (1.58) or corn plus the protected amino acids (1.48). They concluded that energy rather than protein limited weight gains. However, this conclusion may have been misleading because daily consumption of the fishmeal was less than half of the other supplements (.34 vs .80 and .73 kg/day). It was interesting to note that a significant positive relationship ($R^2=.74$, $P<.01$) was found

between average daily gain and intake of fishmeal. This tends to indicate that although cattle reluctantly consumed fishmeal, there was an added response in animal performance with increased fishmeal consumption. Rouquette et al. (1988) reported similar results for calves grazing rye-ryegrass pastures in which average daily consumption of fishmeal and corn were .15 and .51 kg/day for Simmental X Brahman cattle and .20 and .34 kg/day for Brahman cattle. Daily gains of the Simmental X Brahman cattle grazing pasture only, or supplemented with fishmeal or corn were 1.09, 1.15 and 1.26 kg/day. Daily gains of the Brahman cattle were .87, .85 and 1.04 kg/day, respectively.

Anderson et al. (1988) supplemented cattle grazing bromegrass pastures with .58 kg/day of supplements formulated to provide graded levels of escape protein (0, .11, .23 and .34 kg/day) using bloodmeal and corn gluten meal. Increasing levels of escape protein resulted in significant linear ($P<.01$) and quadratic ($P<.05$) increases in rate of weight gain.

Protein Supplementation on Wheat Pasture

Grigsby (1982) attempted to evaluate the responses of stocker cattle grazing winter wheat pasture to additional protein in two experiments. In the first experiment, heifers received either no supplement or 11, 26 or 38% CP supplements using soybean meal to provide the additional protein. Supplements were fed 3 times weekly at the rate of

1.36 kg DM/head/day. Heifers receiving the 11 and 26% CP supplements gained 20% faster (P<.05; .67 vs .80 kg/day) than the unsupplemented controls while no additional response was seen for the supplement above 26% crude protein. In the second trial, steers received either no supplement, an 11% CP supplement with or without monensin (160 mg/head/day), or a 23% CP supplement. Again, soybean meal was used as the primary protein source. Supplements were fed 3 times weekly at a rate of .92 kg DM/head/day. Daily weight gains were 21% higher (P<.05; .80 vs .66 kg/day) for steers receiving the 11% CP supplements and were increased by an additional .07 kg/day with the inclusion of monensin. As a result of these experiments, Grigsby concluded that optimum performance of stocker cattle could be achieved by feeding low levels (< 1 kg DM/head/day) of grain-based supplements containing monensin. One possible explanation for the lack of response to additional protein could be related to the protein source used. Vogel (1988) found that wheat forage is extensively degraded in the rumen and it is unlikely that supplementation with a protein source high in ruminal degradability would have any benefit.

Other studies however, have been consistent with the idea that performance of stocker cattle can be increased when fed a high ruminal bypass protein source. Lee (1985) found that steers grazing wheat pasture and receiving .68 kg/day of a supplement containing 15% meat meal gained 9% faster (P<.05; 1.09 vs 1.00 kg/day) when compared to the

same hominy-based supplement without meat meal. Anderson et al. (1987) also reported that steers receiving .68 kg/day of supplemental feed using meat and bone meal and feather meal as protein sources resulted in an 8.1% increase (P<.05; 1.03 vs .91 kg/day) in rate of weight gain over calves fed a dry rolled corn based control supplement.

Andersen (1988) reported that supplementation of stocker cattle grazing wheat pasture with meat meal resulted in slight (P<.10) increases in forage intake of approximately 4 to 14%. Based on the equations of the net energy system (NRC, 1984) for a 200 kg medium frame steer consuming 2.5% of body weight, a 7% increase in wheat forage intake would increase rate of weight gain by .1 kg/day which is similar to that observed in the trials of Lee (1985) and Anderson (1987). This assumes the NEm and NEg of wheat forage are 1.73 and 1.11 Mcal/kg DM, respectively (Vogel, 1988).

Vogel et al. (1989) reported increased weight gains of stocker cattle grazing wheat pasture and supplemented with either energy or protein supplements. Cattle grazed wheat pasture and received no supplement or were fed .91 kg/head/day of either a corn-based energy supplement or protein supplements that contained meat meal, meat and bone meal or mechanically produced cottonseed meal. Rate of weight gain was increased (P<.03) approximately .10 kg/head/day when cattle were supplemented with either corn, meat meal (or meat and bone meal) or cottonseed meal based

supplements. Although rate of weight gain was greater when cattle received supplements containing meat meal (or meat and bone meal) or cottonseed meal (.90 and .93 vs .81 control and .87 corn), the increase was not significant (P>.30). However, calculated efficiency of supplement use improved from 11.4 kg supplement per kg of increased weight gain for cattle receiving the corn-based supplement to 7.2 and 6.2 kg supplement per kg of added gain for cattle receiving the meat meal and cottonseed meal supplements, respectively. Their results suggested that stocker cattle performance could be improved by low levels of supplementation, but the choice of supplement (i.e. energy vs protein) did not affect weight gains.

Summary

In summary, wheat pasture is a high quality forage that is high in CP, is highly digestible and contains large amounts of soluble N and NPN. It has been shown that the amount of degradability of the N in the rumen affects N flow to the small intestine. A large percentage of the N ingested may not reach the small intestine as it is broken down into NH_3 and microbial protein. Indeed, it has been reported that when forage CP exceeds 15.3%, the NAN flow to the small intestine is less than N intake. Researchers have also shown that increased N flow to the small intestine has improved animal performance. Since wheat forage is high in CP which is rapidly degraded in the rumen, the concept that

animal performance on wheat pasture is not limited by protein might be mistaken. Studies conducted with "high bypass" protein supplementation have shown mixed results to date. Further investigation into this area is warranted as the grazing of wheat pasture is of great economic importance in the southern Great Plains region.

CHAPTER III

EFFECT OF PROTEIN SUPPLEMENTATION ON PERFORMANCE OF STOCKER CATTLE GRAZING WHEAT PASTURE

Abstract

Two trials were conducted to evaluate effects of supplemental protein on weight gains of stocker cattle grazing wheat pasture. Twenty-seven fall-weaned heifers (heifer trial) and eighty fall-weaned steer calves (steer trial) were used. The calves were randomly allotted by weight within breed groups to three (heifers) and four (steers) treatments. The individual heifers were considered replications while there were two replications with the steers in a randomized complete block design. Calves received no supplement (trt 1) or were fed daily .91 kg/head of a corn-based energy supplement that contained (DM basis) 8.7% CP (trt 2) or supplements that contained about 21% CP and 34% mechanically produced cottonseed meal (CSM, trt 3) or 22% corn gluten meal (CGM, trt 4, steers only). All supplements were isocaloric. Daily gains of the heifers were .66 (trt 1), .77 (trt 2) and .80 (trt 3) kg. Supplementation tended ($P<.09$) to improve gains, regardless of type. Daily gains of the steers were 1.10, 1.22, 1.27

and 1.24 kg for treatments 1 through 4, respectively. Regardless of supplement type, supplementation increased ($P<.03$) gains. Gains were not increased ($P<.10$) by the CSM or CGM supplements as compared with the energy supplement. These findings do not support the idea that performance of growing beef cattle grazing wheat pasture is improved by supplemental protein.

Introduction

Wheat pasture is a high quality forage that commonly contains 20 to 30% crude protein on a dry matter basis. However, large amounts of soluble non-protein nitrogen (NPN) are present in the crude protein fraction (Johnson et al., 1974; Horn et al., 1977). Beever and Siddons (1986) reported as much as 30% of ingested nitrogen (N) from fresh forages containing medium to high levels of N may be lost prior to the small intestine. Losses as large as 40 to 45% of ingested N prior to the small intestine have also been reported (Egan, 1974; Egan and Ulyatt, 1980: Ulyatt and Egan, 1979). Vogel (1988) and Andersen (1988) reported that non-ammonia N flow to the small intestine of cattle grazing immature wheat forage ranged from 36 to 63% of N intake. Because of the rapid rate of degradation of wheat forage N in the rumen and loss of ammonia-N that is not incorporated into microbial protein, performance of rapidly growing cattle on wheat pasture may be decreased by flow of inadequate amounts of protein to the small intestine

(Beever, 1984: Vogel et al., 1987). The objective of this study was to determine the effect of feeding additional supplemental protein of low ruminal degradability on weight gains of stocker cattle grazing wheat pasture.

Experimental Procedure

Cattle and Experimental Design

Two grazing trials were conducted using fall-weaned Hereford and Hereford X Angus cattle. The cattle were vaccinated for IBR, BVD and PI_3 and with 7-way Clostridium, treated for internal and external parasites and the steers implanted with Ralgro.

Twenty-seven heifers grazed wheat pasture at the Oklahoma State University Beef Center for 91 days (January 5, 1989 to April 6, 1989). Stocking density was 1.91 head/hectare. The heifers weighed an average of 248 $\pm$ 3.84 kg and were allotted by weight within breed to one of three treatments in a randomized complete block design. Each animal was used as a replication, giving nine replications per treatment. Treatments were a non-supplemented control (Trt 1), a corn-based energy supplement (Trt 2) and a cottonseed meal (mechanically extracted) supplement (Trt 3). The heifers were fed .91 kg of supplement $\cdot head^{-1} \cdot d^{-1}$ in individual stalls in a covered stall barn. Supplement composition is shown in Table 1. Supplement samples were taken weekly and composited by month. Composited samples

were ground through a 2mm mesh screen in a Wiley Mill and analyzed for total N by the Kjeldahl procedure (AOAC, 1975).

Eighty steers, weighing an average of 227 ± 5.59 kg, were allotted by weight within breed to one of four treatments in a randomized complete block design with two replications. The treatments were (Trt 1) a non-supplemented control that received free choice mineral supplement[1], (Trt 2) a corn-based energy supplement, (Trt 3) a cottonseed meal[2] supplement and (Trt 4) a corn gluten meal[3] supplement. The steer trial was conducted at the Forage and Livestock Research laboratory (USDA/ARS, El Reno, OK) and ran for 92 days (December 8, 1988 to March 10, 1989). Stocking density was 1.24 head/hectare on wheat pasture (TAM 101) that was produced by minimum tillage and received 90 kg of N/hectare. Cattle in treatments 2, 3 and 4 received .91 kg/head (as-fed basis) of the supplements daily. Composition of the supplements is shown in Table 2. The steers were group fed supplements, consumption was good and there were no refusals. Supplement samples were taken weekly and composited by month. Composited supplement samples were ground through a 2mm mesh screen in a Wiley Mill and analyzed for total N by the Kjeldahl procedure (AOAC, 1975).

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[1]Green Pasture Mineral. Farmland Industries. Guaranteed Analysis: Ca 13-15%, P 6.0%, Mg 10% and salt 20-23%.
[2]Cottonseed meal produced by mechanical extraction. Traders Oil Mill, Fort Worth, TX.
[3]Obtained from American Fructose, Dimmitt, TX.

In both trials, the energy and protein supplements contained, respectively, 8.6 and 20.2% crude protein (CP) on a DM basis. The supplements were isocaloric and contained equivalent amounts of calcium, phosphorus and magnesium. Supplements also contained monensin at a level to provide 144 mg monensin/head/day (DM basis). The level of supplementation was approximately 1.5% of metabolic body weight.

Because of severe weather (cold and(or) snow and ice cover) the heifers were fed prairie hay over a period of 33 days (February 2 thru March 11) at approximately 7.08 kg $\cdot head^{-1} \cdot d^{-1}$ (as-fed basis). Due to the relatively mild and open winter in El Reno, the steers were fed no hay during the trial. Cattle were weighed after overnight shrinks of about 16 h in drylot without feed or water.

Two in situ trials (December 18-19, 1989 and January 30-31, 1990) were conducted to characterize the ruminal degradability of the sources of supplemental protein used in the cattle trials and subsequent lamb trials. Soybean meal was included as a control. The procedure is outlined in the Appendix.

Statistical Analysis

Data were analyzed by least squares analysis of variance using the General Linear Models (GLM) procedure of SAS (SAS, 1982). The model for the heifers included treatment, breed and breed x treatment as sources of

variance. The breed x treatment interaction was tested by the residual error and when found to be not significant was used as the error term for testing treatment differences. Orthogonal contrasts were conducted to test the following effects: 1) no supplement vs supplementation and 2) energy vs protein supplementation. The model for the steers included treatment, replication, breed, treatment x breed and treatment x replication interactions as sources of variance. The treatment x replication interaction was used as the error term for testing treatment differences. In addition, orthogonal contrasts were conducted to test for the following effects: 1) no supplement vs supplementation, 2) energy vs protein supplementation and 3) cottonseed meal vs corn gluten meal supplementation (source of protein).

Results and Discussion

Heifer Growth Trial

Mean initial, intermediate and final weights of the heifers , along with average daily gains, are shown in Table 3. In the first period (January 5 to February 17), daily gains of the cattle were increased ($P<.01$) at least .21 kg by supplementation and increased ($P<.01$) .13 kg by energy over protein. During the second period of the trial (February 17 to April 6) there was a severe cold spell and hay was fed as the wheat pasture was very limited. Forage availability was evaluated on February 8, 1989 and was 46.39

kg DM/hectare and 8.27 kg DM/100 kg body weight (BW). During this period the cattle fed the energy supplement had decreased gains as compared with the non-supplemented and protein supplemented cattle, however they were not significant. Although gains across all treatments were lower in the second period, they were the highest for the protein supplemented cattle. This could be explained by the large amounts of hay fed which would favor a response to additional protein supplementation. Overall gains (for the entire 91-day trial) tended ($P<.09$) to be improved by supplementation and were higher for the protein supplemented group than the energy supplemented group (although not significantly). This could be explained by the large amounts of hay fed during the second period, on which the supplemental protein would be beneficial. It could also be due to the fact that the wheat pasture was very limited during the second period and the cattle were probably using the supplemental protein more efficiently than the energy supplement.

Steer Growth Trial

Mean initial and final weights of the cattle, daily gains for the entire 92-day trial and efficiency of supplement utilization are shown in Table 4. Daily gains of the cattle were increased ($P<.03$) about .14 kg by the overall effect of supplementation. Final weights of the supplemented groups, regardless of type of supplement, were

greater (P<.01) than the non-supplemented control. The cottonseed meal and corn gluten meal supplements did not increase (P>.50) gains as compared with the corn-based supplement, however, the protein supplements tended to increase final weights of the cattle when compared to the energy supplement (345 and 343 vs 339 kg, respectively; P<.08). Source of supplemental protein did not influence gains. These results are similar to those reported by Horn et al. (1989) in which cottonseed meal from the same source and meat and bone meal or meat meal were used as the sources of high bypass protein.

Ruminal degradability of feedstuffs varies with type of diet and level of feed intake (Zinn and Owens, 1983; Goetsch and Owens, 1985). Vogel et al. (1988) and Vogel (1988) characterized ruminal N degradation of several high protein feedstuffs in cattle grazing wheat pasture. Ruminal N degradation of cottonseed meal produced by the mechanical process was 49% and was less than 66% for cottonseed meal produced by direct solvent extraction. Ruminal degradabilities of meat and bone meal and meat meal were 44 and 52%, respectively.

The in situ trials run in December and January showed similar values as those reported by Vogel et al. (1988) and Vogel (1988). Escape N values for the feedstuffs are shown in Table 5. Although two steers were used in each trial, the variance between animals was not significant and values shown were pooled across animals.

Calculated efficiencies of supplement use in this trial were 7.3, 5.5 and 8.0 kg of supplement (as-fed) per kg of increased gain for cattle fed the energy , cottonseed meal and corn gluten meal supplements, respectively. Differences among efficiencies of supplement use were not significant (P>.45). Forage availability was evaluated at the beginning and ending of the trial (December 13, 1988 and March 8, 1989). The forage availability data is shown in Table 6.

Lee (1985) reported that weight gains of calves grazing wheat pasture and fed .68 kg/day of a supplement containing 15% meat meal were increased .09 kg/day as compared with a control, hominy feed-based supplement. Anderson et al. (1987) reported a similar gain response by stocker cattle grazing wheat pasture fed .68 kg/head/day of a supplement that contained 11.5% feather meal and 19.4% meat and bone meal. Our studies are not in agreement with these studies. Differences in amounts of available wheat forage, the number of days of snow and(or) ice cover and the amounts of other supplemental feeds that were fed may account for part of the discrepancy of results. In the study of Anderson et al. (1987), cattle had free-choice access to wheat hay throughout the 79 days of grazing wheat pasture and free-choice access to corn silage during 21 days of the trial when snow cover "inhibited grazing". This fairly high level of supplementation with wheat hay and corn silage would favor a response to additional supplemental protein. If protein supplementation of growing cattle on wheat pasture does

increase weight gains, the response may be due to an increased flow of protein to the small intestine or to an improvement in protein quality (i.e., composition of amino acids absorbed from the small intestine). Studies of amino acid imbalance with nonruminants have shown marked improvement in N balance, which was almost totally due to decreased excretion of urinary N, as amino acid quality of the diet improved (Cromwell et al., 1969). Studies with ruminants (Egan and Moir, 1965) have shown that improvements in the amount and(or) relative proportions of amino acids flowing into the duodenum increases feed intake. However, results from companion lamb trials by Smith (1990) do not lend support to either mechanism (i.e., improvement in N retention or forage intake) by which protein supplementation may increase gains of growing cattle on wheat pasture.

TABLE 1

COMPOSITION OF SUPPLEMENTS (DM BASIS) FED TO HEIFERS

Item	Corn	Cottonseed meal[a]
Corn, ground, %	77.80	53.05
Cottonseed meal, %		31.44
Cottonseed hulls, %	5.98	.36
Dehydrated alfalfa, %	4.00	4.00
Sugarcane molasses, %	4.20	4.20
Dicalcium phosphate, %	3.95	2.37
Calcium carbonate, %	2.74	3.51
Magnesium oxide, %	.45	.20
Salt, %	.45	.45
Trace-mineralized salt, %	.30	.30
Rumensin 60 Premix, %[b]	.13	.13
---------- Nutrient composition ----------		
Crude protein, %		
Calculated	8.64	20.20
Analyzed	8.94	20.53
Calcium, %	2.00	2.00
Phosphorus, %	1.00	1.00
Magnesium, %	.40	.40
NE_{Gain}, Mcal/kg	1.23	1.23

[a]Produced by mechanical process. Traders Oil Mill, Fort Worth, TX.
[b]Supplied 158 mg monensin/kg (as-fed).

TABLE 2

COMPOSITION OF SUPPLEMENTS (DM BASIS) FED TO STEERS

Item	Corn	CSM[a]	CGM[b]
Corn, ground, %	77.80	53.05	56.57
Cottonseed meal, %		31.44	
Corn gluten meal, %			20.53
Cottonseed hulls, %	5.98	.36	6.81
Dehydrated alfalfa, %	4.00	4.00	4.00
Sugarcane molasses, %	4.20	4.20	4.20
Dicalcium phosphate, %	3.95	2.37	3.72
Calcium carbonate, %	2.74	3.51	2.84
Magnesium oxide, %	.45	.20	.46
Salt, %	.45	.45	.45
Trace-mineralized salt, %	.30	.30	.30
Rumensin 60 Premix, %[c]	.13	.13	.13
---------- Nutrient composition ----------			
Crude protein, %			
Calculated	8.64	20.20	20.20
Analyzed	8.71	19.90	18.70
Calcium, %	2.00	2.00	2.00
Phosphorus, %	1.00	1.00	1.00
Magnesium, %	.40	.40	.40
NE_{Gain}, Mcal/kg	1.23	1.23	1.23

[a]Cottonseed meal, produced by mechanical process. Traders Oil Mill, Fort Worth, TX.
[b]Corn gluten meal. American Fructose. Dimmitt, TX.
[c]Supplied 158 mg monensin/kg (as-fed).

TABLE 3

EFFECT OF PROTEIN SUPPLEMENTATION ON PERFORMANCE OF GROWING HEIFERS ON WHEAT PASTURE

	Supplement				Contrasts[a]	
	None	Energy	Cottonseed meal[b]	SEM[c]	1	2
Number of cattle	9	9	9			
Supplement consumption, kg/head/day	0	0.91	0.91			
Initial weight, kg	245	248	244	6.1		
Intermediate weight, kg	282	299	289	6.9	NS	NS
Final weight, kg	305	318	316	7.0	+	NS
ADG, 1st period (43 d), kg	.86	1.20	1.07	0.04	**	**
ADG, 2nd period (48 d), kg	.49	.39	.56	0.05	NS	NS
ADG, overall (91 d), kg	.66	.77	.80	0.03	+	NS

[a]1 = no supplement vs supplement. 2 = energy vs protein supplement. ** = (P<.01). + = (P<.10). NS = not significant (P>.10).
[b]Produced by mechanical extraction.
[c]Standard error of the mean.

TABLE 4

EFFECT OF PROTEIN SUPPLEMENTATION ON PERFORMANCE OF GROWING STEERS ON WHEAT PASTURE

	Supplement					Contrasts[a]		
	None	Energy	CSM[b]	CGM[c]	SEM[d]	1	2	3
Number of cattle	20	20	20	20				
Supplement consumption, kg/head/day	0	0.91	0.91	0.91				
Initial weight, kg	228	226	228	229	6.1			
Final weight, kg	330	339	345	343	6.8	**	+	NS
Daily gain (92 d), kg	1.10	1.22	1.27	1.24	0.03	*	NS	NS
Efficiency of supplement use[e]		7.3	5.5	8.0	1.9		NS	NS

[a]1 = no supplement vs supplementation. 2 = energy vs protein supplementation. 3 = cottonseed meal vs corn gluten meal supplementation. ** = (P<.01). * = (P<.05). + = (P<.10) NS = not significant (P>.10).
[b]Cottonseed meal, produced by mechanical extraction.
[c]Corn gluten meal.
[d]Standard error of the mean.
[e]kg of supplement (as-fed) per kg of increased gain.

TABLE 5

RUMINAL ESCAPE NITROGEN VALUES FOR HIGH PROTEIN FEEDSTUFFS ON IMMATURE WHEAT PASTURE - DECEMBER, 1989 AND JANUARY, 1990

	Trial[a]	
	December	January
Feedstuff[b]	%	%
Soybean meal	16.97	15.42
Cottonseed meal, mechanically produced[c]	55.14	61.01
Cottonseed meal, mechanically produced[d]	52.41	61.46
Cottonseed meal[e]	31.19	48.68
Corn gluten meal[f]	76.99	83.46
Blood meal[g]	80.20	91.78
Feather meal[h]	88.19	92.51
Milo distillers dried grains	70.16	72.55
Meat and bone meal	49.67	52.59

[a]Values from trials were significantly different (P<.001).
[b]Feedstuffs were significantly different (P<.001).
[c]Traders Oil Mill, Fort Worth, TX. 1989.
[d]Traders Oil Mill, Fort Worth, TX. 1987.
[e]Producers Cooperative, Oklahoma City, OK.
[f]American Fructose, Dimmitt, TX.
[g]Black Industries, Concordia, MO.
[h]River Valley By-Products, Fayetteville, AR.

TABLE 6.

FORAGE AVAILABILITY FOR STEERS GRAZING WHEAT PASTURE

	Replication 1				Replication 2			
Treatment	Control	Corn	CSM	CGM	Control	Corn	CSM	CGM
December 13, 1988								
kg DM/hectare	1117.3	829.7	1004.3	1219.5	1588.0	923.7	2080.4	1253.6
kg DM/100 kg BW[a]	397.4	298.9	353.9	425.7	559.0	329.5	743.0	444.1
March 8, 1989								
kg DM/hectare	454.5	395.1	562.5	716.5	1990.5	592.9	841.2	723.5
kg DM/100 kg BW	108.9	92.0	129.1	166.0	490.7	142.7	198.0	169.6

[a]Body weight.

CHAPTER IV

EFFECT OF PROTEIN SUPPLEMENTATION ON FORAGE INTAKE AND NITROGEN BALANCE OF LAMBS FED FRESH HARVESTED WHEAT FORAGE

Abstract

Studies using twenty-eight (33 kg) and twenty-five (30 kg) fine wool crossbred wether lambs were conducted to evaluate the effects of supplemental protein on forage intake and nitrogen (N) balance of lambs fed harvested wheat forage in stalls. The animals were allotted to four (Trial 1) and five (Trial 2) treatments in a randomized complete block design with 7 and 5 replications, respectively. Lambs received no supplement (trt 1) or 200 g/head/day of a corn-based energy supplement (8.7% CP DM basis, trt 2) or supplements that contained about 21% CP and 36% mechanically produced cottonseed meal (CSM, trt 3) or 22% corn gluten meal (CGM, trt 4) in Trial 1. Trial 2 consisted of the same treatments 1 and 2 with three additional supplements that provided about 26% CP and 48% mechanically produced CSM (trt 3), 10% feather meal and 16% CGM (FTM/CGM, trt 4) or 10% blood meal and 16% CGM (BM/CGM, trt 5). All supplements were isocaloric. Lambs in Trial 1 treatments 1 through 4

consumed 65, 60, 58 and 63 g of forage DM/kg metabolic body weight (MBW), respectively. Supplementation had no effect (P>.10) on forage intake. In Trial 2, lambs of treatments 1 through 5 consumed 80, 60, 67, 63 and 63 g of forage DM/kg MBW, respectively. Supplementation, regardless of type, decreased (P<.01) forage intake. In both trials N retention of the lambs, expressed as g/d, % of N intake and % of absorbed N, was not influenced (P>.05) by treatment or type of supplement. These data do not support the concept that performance of animals grazing wheat pasture is limited by flow of inadequate amounts of protein to the small intestine.

Introduction

Wheat pasture is a high quality forage that commonly contains 20 to 30% crude protein. However, Beever and Siddons (1986) reported that as much as 30% of ingested N, from fresh forages containing medium to high levels of N, may be lost prior to the small intestine. Vogel (1988) reported that approximately 50 to 75% of wheat forage N exists in a highly soluble rapidly disappearing pool with rates of N disappearance of 16 to 19%/h. Beever (1984) concluded that the performance of animals grazing fresh temperate forages is limited by the supply of NAN flowing to the small intestine. This could also be due to, or cause, an amino acid imbalance. The classical response of an amino acid imbalance is decreased feed intake and rate of gain

which can be corrected by supplementation of the limiting amino acid (Harper and Benvenga, 1978). Egan and Moir (1965) and Egan (1965a) found that duodenal infusions of casein, in lambs fed a low protein roughage diet, initiated an improvement in DM and digestible energy intake which was related to improved N retention. Schelling and Hatfield (1968) reported that abomasal infusions of casein in lambs improved N retention and voluntary feed intake. With these results in mind, the objective of this research was to study the effect of "high bypass" protein supplementation on forage intake and N retention of lambs fed fresh harvested wheat forage in metabolism stalls.

Experimental Procedure

Two lamb trials were conducted at the Forage and Livestock Research laboratory (USDA/ARS, El Reno, Oklahoma) to evaluate the effects of supplemental protein on voluntary intake of wheat forage and nitrogen (N) balance.

Twenty-eight fine wool cross wether lambs (33 $\pm$ 1.8 kg) were used in a randomized complete block design in the first trial (November 9 thru December 6, 1988). The lambs were blocked according to weight and location in the metabolism barn. Treatments consisted of a non-supplemented control group, a corn-based energy supplement and two supplements that provided 2.5-times as much protein as the energy supplement. All supplements were corn-based with additional protein supplied by cottonseed meal (mechanically produced)

or corn gluten meal. Composition of the supplements is shown in Table 1. The supplements were isocaloric and contained no monensin. Additional Ca, P or Mg were not added to the supplements so that their availability from the wheat forage could be evaluated in another study. This trial lasted for 28 days with an 18-day adaptation period and two consecutive 5-day forage intake and fecal and urine collection periods.

The second lamb trial (April 21 thru May 2, 1990) used 25 fine wool cross wether lambs (30 $\pm$ 2.5 kg). The wethers were used in a randomized complete block design with lambs blocked according to weight and location in the metabolism barn. This trial consisted of five treatments that included a non-supplemented control, an energy supplement and three supplements that provided 3-times as much protein as the corn-based energy supplement. All supplements were corn-based with additional protein supplied by cottonseed meal (mechanically produced), a feather meal/corn gluten meal mixture or a blood meal/corn gluten meal mixture. Composition of the supplements is shown in Table 2. The supplements contained no additional Ca, P or Mg, were isocaloric and contained no monensin. The second trial lasted for 12 days with a 7-day adaptation period and one 5-day forage intake and fecal and urine collection period.

In both trials, lambs were allowed ad libitum access to fresh harvested wheat forage for 21 to 22 h daily. The forage was harvested each morning with a Carter Forage

Harvester. Refused wheat forage was removed daily at 0730 h and water and either 0 or 200 g of the supplements were given to the lambs. The amount of supplement fed to the lambs was approximately 1.5% of metabolic body weight. This level was equivalent to the rate of supplementation in the cattle trials, which was also approximately 1.5% of metabolic body weight. All supplements were consumed in 10 to 15 minutes each day and there were no orts. After a 2- to 3-h period, the lambs were given freshly harvested wheat forage. Fresh harvested forage was sampled and dried daily for analysis. Refused forage was weighed daily for each lamb individually and then composited, sampled and dried for analysis. Supplement samples were taken daily and composited across days within period for analysis in the first trial. Supplement samples were taken daily and composited for the 5 day period in the second trial.

Total feces and urine were collected daily. Feces were dried in a forced air oven at 40^{o}C. Prior to analysis, fecal collections were composited by animal (across days within period for Trial 1) and were mixed, ground through a 2mm screen in a Wiley mill and samples taken. Daily urine collections were acidified with 10 ml of 50% concentrated sulfuric acid, weighed individually and then diluted with water to a constant weight of 4 kg. A two percent aliquot was collected and composited by animal (across days within period for Trial 1). Urine samples were frozen until analysis. Total nitrogen content of the wheat forage,

supplements, feces and urine was determined by the Kjeldahl procedure (AOAC, 1975).

Soluble N was determined on forage from the same cuttings fed to the lambs. The data were taken from simultaneous experiments at the Forage and Livestock Research laboratory. The N content was fractionated into soluble N and NPN (non-protein nitrogen) by blending 5 g of frozen forage (immediately frozen after forage sample taken from harvested forage) with 200 ml of buffer (1.13 g Na_2HPO_4, 1.09 g NaH_2PO_4, 0.43 g KCl, 0.43 g NaCl, 0.104 g $MgSO_4 \cdot 5\ H_2O$ and 0.15 g K_2SO_4/liter, pH 6.5) followed by a 1 hour incubation at 39^{o}C. The remaining procedure was as reported by Gallavan et al. (1989). The total N, soluble N and NPN values for the forages in both lamb trials are shown in Table 3. Analysis was not conducted at Oklahoma State University due to loss of samples when freezers went down.

Data were analyzed by least squares analysis of variance using the General Linear Models (GLM) procedure of SAS (SAS, 1982). The sources of variation included in the GLM procedure for the first trial were treatment, block, period, treatment x block and treatment x period interactions. The treatment x block interaction was used as the error term in testing treatment effects. In addition, orthogonal contrasts were conducted to test for the following effects: 1) no supplement vs supplementation, 2) energy vs protein supplementation and 3) cottonseed meal vs corn gluten meal supplementation (i.e., source of protein).

Sources of variation for the second trial included treatment, block and the treatment x block interaction, which was used as the error term. Four orthogonal contrasts were conducted to test the following: 1) no supplement vs supplementation, 2) energy vs protein supplementation, 3) cottonseed meal vs feather meal/corn gluten meal and blood meal/corn gluten meal supplementation (source of protein) and 4) feather meal/corn gluten meal vs blood meal/corn gluten meal supplementation (difference in amino acid profile).

Results and Discussion

Effects of the different supplements on wheat forage intake and N balance of the lambs in Trial 1 are shown in Table 4. The treatment x period interaction was not significant ($P>.15$) for any of the measurements, therefore, the data were pooled across periods. Wheat forage intake ranged from 58 to 65 g DM/kg metabolic body weight (MBW). Supplementation had no effect ($P>.10$) on forage intake. The effect of type of supplement (i.e., energy vs protein or source of protein) on forage intake was not significant ($P>.50$). Total DM intake and intake of digestible DM were increased ($P<.005$) by supplementation, as would be expected. Nitrogen retention, expressed as g/day, % of N intake and % of absorbed N, was not affected ($P>.20$) by supplementation. However, N retained as g/day tended to be improved ($P<.10$)

by protein supplementation when compared to the energy supplement.

Effects of the different supplements on forage intake and N balance for lambs in Trial 2 are shown in Table 5. Wheat forage intake ranged from 60 to 80 g DM/kg MBW. Supplementation decreased ($P<.01$) forage intake. The effect of type of supplement (energy vs protein or protein source) on forage intake was not significant ($P>.40$). Total DM intake and intake of digestible DM were not affected ($P>.35$) by treatment or type of supplement. Nitrogen retention, expressed as g/day, % of N intake and % of absorbed N, was not affected ($P>.10$) by the overall effect of supplementation, regardless of type of supplement.

Values for N retention as % of N intake and % of absorbed N were much higher in Trial 2 than Trial 1. This could be due to several reasons. The lambs in Trial 2 were smaller but ingested more forage per kg metabolic body weight than the lambs in Trial 1. Also, the wheat forage fed in Trial 2 had less soluble N than the wheat forage in Trial 1. Therefore it would be less rapidly degraded in the rumen, allowing more N to the small intestine. Although the values for Trial 2 are high, they are similar to those reported by van der Veen et al. (1989) in which alpha-ketoglutarate was administered to lambs to determine its effects on N metabolism.

Corn gluten meal has been criticized as a source of bypass protein due to the fact that, although it is high in

sulfur-containing amino acids, it is low in lysine. Blood meal is very high in lysine. The combination of blood meal with corn gluten meal complements each other with regard to amounts of lysine and the sulfur-containing amino acids. Feather meal is also high in lysine and would complement corn gluten meal. Irlbeck et al. (1989) supplemented yearling steers grazing brome pasture with increasing amounts of escape protein from either corn gluten meal or a corn gluten meal/blood meal mixture. Escape protein improved gain but there was no difference between corn gluten meal and corn gluten meal/blood meal as sources of escape protein.

Studies of amino acid imbalance with nonruminants have shown marked improvements in N balance, which was almost totally due to decreased excretion of urinary N, as amino acid quality of the diet improved (Cromwell et al., 1969). Studies with ruminants (Egan and Moir, 1965; Egan, 1965; Schelling and Hatfield, 1968) have shown that improvements in the amount and(or) relative proportions of amino acids flowing into the duodenum increases feed intake and improves N balance. However, results from these lamb trials do not lend support to either mechanism (improvement in N retention or forage intake) by which protein supplementation may increase gains of growing ruminants on wheat pasture.

TABLE 1

COMPOSITION OF SUPPLEMENTS (DM BASIS) FED TO LAMBS (TRIAL 1)

Item	Corn	CSM[a]	CGM[b]
Ground corn, %	85.39	57.32	61.28
Cottonseed meal, %		35.83	
Corn gluten meal, %			23.33
Cottonseed hulls, %	9.76	2.00	10.54
Sugarcane molasses, %	4.30	4.30	4.30
Salt, %	.55	.55	.55
----------Nutrient composition----------			
Crude protein, %			
Calculated	8.76	21.90	21.90
Analyzed	8.88	21.90	22.34
NE_g, Mcal/kg	1.32	1.32	1.32

[a]Cottonseed meal, produced by mechanical extraction. Traders Oil Mill, Fort Worth, TX.
[b]Corn gluten meal. American Fructose, Dimmitt, TX.

TABLE 2

COMPOSITION OF SUPPLEMENTS (DM BASIS) FED TO LAMBS (TRIAL 2)

Item	Corn	CSM[a]	FTM/CGM[b]	BM/CGM[c]
Ground corn, %	85.39	44.25	60.34	59.05
Cottonseed meal %		48.26		
Corn gluten meal[d], %			16.32	16.43
Feather meal[e], %			10.39	
Blood meal[f], %				10.39
Cottonseed hulls, %	9.76	2.64	8.10	9.28
Sugarcane molasses, %	4.30	4.30	4.30	4.30
Salt, %	.55	.55	.55	.55
----------Nutrient Composition----------				
Crude protein, %				
Calculated	8.76	26.28	26.28	26.28
Analyzed	9.84	22.59	24.94	24.69
NE_g, Mcal/kg	1.32	1.32	1.32	1.32

[a]Cottonseed meal produced by mechanical extraction. Traders Oil Mill, Fort Worth, TX.
[b]Feather meal/corn gluten meal.
[c]Blood meal/corn gluten meal.
[d]American Fructose, Dimmitt, TX.
[e]River Valley ByProducts, Fayetteville, AR.
[f]Black Industries, Concordia, MO.

TABLE 3

TOTAL NITROGEN (N), SOLUBLE NITROGEN AND NON-PROTEIN NITROGEN (NPN) OF WHEAT FORAGE FED LAMBS

Date	Total N, % DM	Soluble N, % Total N	NPN, % Total N	NPN, % Soluble N
Trial 1 (Nov. 9 - Dec. 6, 1988)				
Nov. 9	3.35	12.8	8.6	67.4
Nov. 11	2.97	47.8	25.6	53.5
Nov. 16	3.36	53.9	33.3	61.9
Nov. 18	3.37	47.8	29.7	62.1
Nov. 21	3.11	21.2	13.5	63.6
Nov. 23	2.81	44.5	29.5	66.4
Nov. 25	2.86	45.4	30.4	66.9
Nov. 28	2.75	73.4	39.3	53.5
Nov. 30	3.20	43.7	22.5	51.4
Dec. 2	2.47	38.9	*	*
Dec. 5	2.92	56.5	35.3	62.4
Trial 2 (April 21 - May 2, 1989)				
April 21	2.63	58.5	23.6	40.2
April 24	2.36	43.2	26.7	61.8
April 26	2.36	47.9	28.0	58.4
April 28	1.83	46.4	21.8	47.0
May 1	1.94	52.1	26.8	51.5

*Missing values.

TABLE 4

LEAST SQUARE MEANS VALUES FOR EFFECT OF PROTEIN SUPPLEMENTATION ON WHEAT FORAGE INTAKE AND NITROGEN RETENTION OF LAMBS (TRIAL 1)

	Supplement					Contrasts[a]		
	Control	Energy	CSM[b]	CGM[c]	SEM[d]	1	2	3
Number of lambs	7	7	7	7				
Supplement intake, g as-fed/d	0	200	200	200				
Initial weight, kg	34	34	34	34	.2			
Final weight, kg	32	33	33	33	.4	**	NS	NS
Wheat forage intake, g DM/kg MBW[e]	65	60	58	63	1.1	NS	NS	NS
Total DM intake, g DM/kg MBW	65	73	71	76	1.1	**	NS	NS
Digestible DM intake, g DM/kg MBW	45	49	50	53	1.0	**	NS	NS
Total N intake, g/d	27.4	28.2	31.2	33.6	.5	**	**	NS
Fecal N excreted, g/d	7.2	10.0	9.1	9.5	.2	**	NS	NS
Urinary N excreted, g/d	14.0	12.1	14.6	16.9	.3	NS	**	*
Nitrogen retention								
g/day	6.3	6.0	7.5	7.3	.5	NS	+	NS
% of N intake	20.9	19.1	21.9	19.0	1.8	NS	NS	NS
% of absorbed N	27.5	27.6	29.5	23.7	3.0	NS	NS	NS

[a]1 = no supplement vs supplementation. 2 = energy vs protein supplementation. 3 = cottonseed meal vs corn gluten meal supplementation. ** = (P<.01), + = (P<.10) and NS = not significant (P>.10).
[b]Cottonseed meal. Produced by mechanical extraction.
[c]Corn gluten meal.
[d]Standard error of the mean.
[e]Metabolic body weight = $WT^{.75}$kg.

TABLE 5

LEAST SQUARE MEANS VALUES FOR EFFECT OF PROTEIN SUPPLEMENTATION ON WHEAT FORAGE INTAKE AND NITROGEN RETENTION OF LAMBS (TRIAL 2)

	Supplement						Contrasts[a]			
	Control	Energy	CSM[b]	FTM/CGM[c]	BM/CGM[d]	SEM[e]	1	2	3	4
Number of lambs	5	5	5	5	5					
Supplement intake, g as fed/d	0	200	200	200	200					
Initial weight, kg	29	30	30	30	30	.2				
Final weight, kg	28	29	28	29	30	.6	+	NS	*	NS
Wheat forage intake, g DM/kg MBW[f]	80	60	67	63	63	4.9	**	NS	NS	NS
Total DM intake, g DM/kg MBW	80	75	82	78	78	4.9	NS	NS	NS	NS
Digestible DM intake, g DM/kg MBW	54	51	55	54	52	3.6	NS	NS	NS	NS
Total N intake, g/d	21.6	19.6	25.3	24.9	24.9	1.4	NS	**	NS	NS
Fecal N excreted, g/d	6.0	6.8	7.8	7.2	7.9	.4	*	NS	NS	NS
Urinary N excreted, g/d	7.1	5.1	8.2	8.3	8.2	.5	NS	**	NS	NS
Nitrogen retention										
g/day	8.5	7.7	9.3	9.4	8.7	.8	NS	NS	NS	NS
% of N intake	37.5	36.7	34.3	36.4	33.8	2.3	NS	NS	NS	NS
% of absorbed N	51.8	55.5	48.7	51.0	49.2	3.3	NS	NS	NS	NS

[a]1 = no supplement vs supplement. 2 = energy vs protein supplement. 3 = source of protein supplement. 4 = feather meal/corn gluten meal vs blood meal/corn gluten meal supplement. ** = (P<.01). * = (P<.05). + = (P<.10). NS = not significant (P>.10).
[b]Cottonseed meal. Produced by mechanical extraction.
[c]Feather meal/corn gluten meal.
[d]Blood meal/corn gluten meal.
[e]Standard error of the mean.
[f]Metabolic body weight = $WT^{.75}$kg.

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APPENDIX

IN SITU PROCEDURE

1. Bags were from Ankom, PO Box 416, Spencerport, NY 14559. They were white polyester with heat sealed seams. Pore size was 53 ± 10 microns and bags were 10 cm X 20 cm.

2. Samples were 3 g of feedstuffs, ground thru a 2 mm screen in a Wiley Mill.

3. Bags and feedstuffs were dried overnight in a drying oven at 50°C.

4. Bags and feedstuffs were allowed to come to room temperature in a desicator. Bag weight was recorded, then the sample was weighed into the bag and the total weight was recorded.

5. Bags were attached to nylon lines that had stainless steel weights on the end. Bags were securely attached using twist ties.

6. Bags were submerged in 40°C water 20 minutes prior to placement in the rumen. Bags were then placed under the mat layer in the rumen.

7. Animal diet was immature wheat pasture.

8. Rumen incubation time was 16 hours; equivalent to 6.25%/hr passage rate.

9. Bags were removed from the rumen and placed in 40oC water for transport to the building. Bags were then placed in a bucket with running warm water to flush out the excess rumen contents. The bucket was dumped and refilled until the water remained clear.

10. Bags were washed individually on the exterior then removed from the lines and water was run through them for approximately one minute. Flow rate was approximately 4 L/min.

11. Bags were hung over a line and allowed to drip dry for 6 hours. Bags were then placed in a forced air oven at 50oC and allowed to dry overnight.

12. Bags were placed in a desicator, allowed to cool to room temperature and then weighed. Total residue and bag weight was recorded.

13. Residues were subsampled and N was determined by micro Kjeldahl procedures.

14. Escape N values were calculated as ((g residue N / g sample N) X 100) to give values as a percentage.

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