RATE AND EXTENT OF RUMINAL DIGESTION OF WHEAT FORAGE AND PROTEIN SUPPLEMENTS BY STEERS GRAZING WHEAT PASTURE

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Story in Brief

Two experiments were conducted to evaluate rate and extent of in situ ruminal nitrogen disappearance of wheat forage and several protein supplements in cattle grazing wheat pasture. In experiment I, soybean meal, cottonseed meal, meat and bone meal, corn gluten meal, fish meal and wheat forage were incubated in situ while in experiment II cottonseed meals produced by direct solvent and mechanical processes and meat meal were studied. Wheat forage nitrogen existed kinetically as two pools with different rates of disappearance (i.e., a highly soluble rapidly disappearing and a less soluble slowly disappearing fraction) in each stage of wheat forage maturity. Rate and extent of nitrogen disappearance was greatest for soybean meal, the 3 cottonseed meals and meat and bone were intermediate, and corn gluten meal, fish meal and meat meal had the lowest values. In addition, method of processing influenced ruminal degradation of nitrogen with cottonseed meal (direct solvent) being greater than cottonseed meal (mechanical). Because of the rapid rate of wheat forage nitrogen disappearance the differences in the rate and extent of nitrogen disappearance of the protein supplements should be considered in formulating supplements for rapidly growing cattle grazing wheat pasture.

(Key Words: Wheat Pasture, Growing Cattle, Protein Supplementation.)

Introduction

Wheat and other small grain forages are high-quality forages and commonly contain 24 to 30% crude protein (CP) on a dry matter basis. Because of the rapid rate of ruminal degradation of wheat forage CP and loss of ammonia-N that is not incorporated into microbial protein, performance of rapidly growing cattle on wheat pasture (WP) may be limited by flow of inadequate amounts of non-ammonia N (NAN) flowing to the small intestine. Lee (1984 and 1985) reported that weight gains of stocker calves fed 1.5 lb/day of a meat and bonemeal containing supplement were increased .20 lb/day as compared with calves fed control, milo- or hominy feed-based supplements.

The objectives of these experiments were to evaluate rate and extent of in situ ruminal disappearance of nitrogen (N) of wheat forage and several high protein supplements in cattle grazing WP. Also, ruminal degradation of N of cottonseed meals produced by direct solvent and mechanical processes and meat meal were measured.

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Experimental Procedure

Experiment I

Eight mature rumen cannulated Hereford steers (1265 ± 64 lb) were used in a split plot design in which steers grazed immature (March 8 to March 30, 1985) and mature (April 23 to May 10, 1985) wheat forage. Steers were allotted by weight to one of two treatments in which they were dosed ruminally with 0 or 300 mg lasalocid daily. Duplicate dacron bags containing approximately 10 g of soybean meal (SBM), cottonseed meal (CSM), meat and bone meal (MBM), fish meal (FSM), and corn gluten meal (CGM) were incubated in situ in the rumen of each steer for 4, 12, 24 and 36 hr. Also, duplicate dacron bags containing approximately 20 g "as is" wheat forage were incubated in situ in the rumen for 4, 8, 12, 18, 24, 36, 48 and 60 hr. Contents of the bags were analyzed for N by the Kjeldahl procedure. Rate of ruminal disappearance of N of the protein supplements was calculated by regression of the natural logarithm (ln) of the percent N remaining with time. Extent of N disappearance after 36 hr in situ was calculated as the difference between initial and final N content expressed as a proportion of initial N content. For wheat forage, plots of ln of the percent N remaining vs time were curvilinear (i.e., two distinct fractions). Consequently, data were analyzed using "curve peeling" to estimate the slopes and intercepts of the two N fractions. Estimates of the N pool size for each fraction were estimated from the anti-logarithm of the intercept. The time required for one-half of the N to disappear in each pool was estimated as ln 2/rate of disappearance.

Experiment II

Fifteen mature multi-cannulated steers (1041 ± 106 lb) were used in a completely randomized experimental design in which steers grazed a common WP for 18 days (March 1 to March 18, 1986) prior to the 3-day experimental period during the immature stage of wheat forage. Steers were allotted by weight to one of three treatments in which cottonseed meals produced by direct solvent and mechanical processes (CSMds and CSMm) and meat meal (MM) were studied. Rate of ruminal passage (k) was estimated by mordanting each meal with chromium (Cr) and regressing Cr concentration of duodenal samples vs time after a 200 g intraruminal dose of the mordanted meal.

In addition, duplicate dacron bags containing 2.5 g of either CSMds, CSMm, or MM were incubated in situ for 4, 8, 12, 24 and 36 hr. N disappearance estimates obtained in situ were fit by a nonlinear equation to estimate potential degradability (p) using the following equation: $p = a + b(1-e^{-ct})$ where a is the highly soluble rapidly disappearing fraction, b is the fraction other than fraction "a" which disappears at a constant fractional rate per unit time, c is the rate constant of fraction "b" and t is time. Using the estimated parameters (i.e., a, b and c), the extent of ruminal N disappearance (RD) was calculated using the equation of Orskov and McDonald (1979) where $RD = a + bc/(c+k)$. The rate constant, k, represents rate of passage obtained from the mordanted supplements.

In both experiments, hand-clipped wheat forage samples were obtained to characterize the forage composition. Wheat forage samples were analyzed for organic matter (OM), total N, soluble N, non-protein N (NPN) and in vitro dry matter digestibility (IVDMD). All protein

supplements were characterized by Kjeldahl N analysis, N solubility in .15 N NaCl, pepsin indigestible N (PIN) and OM.

Results and Discussion

Composition of Wheat Forage and Protein Supplements

The chemical composition of wheat forage and the protein supplements used in experiments I and II are shown in tables 1, 2 and 3, respectively. Differences in maturity of wheat forage in experiment I were reflected by differences in crude protein (24.4 vs 13.2%), and IVDMD values (76.2 vs 65.7%, for immature and mature wheat forage, respectively). Crude protein content (27.2%) and IVDMD (76.4%) of

Table 1. Chemical composition of grazed wheat forage (Experiments I and II).

	Experiment I		Experiment II	SEM
Forage maturity:	Immature	Mature	Immature	(n=3)
Dry matter, %	23.3	27.1	24.8	.87
Organic matter, % of DM	93.7	95.7	90.6	.89
Nitrogen, % of DM				
Total N (CP)[b]	3.91(24.4)	2.11(13.2)	4.35(27.2)	.30
Soluble N	1.42	1.00	1.71	.07
NPN[c]	.45	.32	.65	.09
Soluble N, % of total N	36.3	47.4	39.2	2.30
NPN, % of total N	11.5	15.2	15.2	1.80
IVDMD[d], %	76.2	65.7	76.4	1.21

[a]Standard error of the mean.
[b]Numbers in parentheses = crude protein (CP).
[c]Nonprotein nitrogen
[d]In vitro dry matter digestibility.

Table 2. Composition of protein supplements (Experiment I).

	Protein supplement[a]					SEM[b]
Item, DM basis	SBM	CSM	CGM	MBM	FSM	(n=3)
Organic matter, %	91.85	86.50	94.62	68.26	78.86	2.60
Nitrogen						
Total, %	7.82	6.71	10.50	7.84	9.86	.13
Soluble, % of total	21.21	15.71	7.52	17.17	27.00	2.28
PIN[c], % of total	5.09	11.40	12.85	9.94	3.33	1.06

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

Table 3. Composition of protein supplements (Experiment II).

Item, DM basis	Protein supplements[a]			SEM[b] (n=3)
	CSMds	CSMm	MM	
Organic matter, %	93.57	94.14	75.52	1.02
Nitrogen				
Total, %	6.70	6.84	7.82	.21
Soluble, % of total	17.71	12.55	14.57	1.33
PIN[c], % of total	12.46	15.59	11.74	.75

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

immature wheat forage grazed in experiment II were similar to values for the immature forage in experiment I. Approximately 36 to 47% of total forage N was soluble N, and nonprotein (NPN) accounted for about 11 to 15% of total N in the forage. In general, losses of N from the rumen would be expected to increase with increasing amounts of soluble N in forages. For the protein supplements, total N content ranged from 6.7 to 10.5% of DM with soluble N comprising 7.52 to 27.00% of total N. In experiment I, PIN of the protein supplements ranged from 5.09 to 12.85% of total N while in experiment II, PIN of CSMds and CSMm tended to parallel differences in heat and pressure exposure during processing with PIN increasing from 12.46 to 15.59% for CSMds and CSMm, respectively.

Experiment I

Visual examination of Figures 1 and 2 reveal that two distinct N pools are present in wheat forage. In immature wheat forage, rates of N disappearance were obtained between 4 and 24 hr and 24 and 60 hr of incubation while in mature wheat forage, rates of N disappearance were obtained between 4 and 12 hr and 12 and 60 hr of incubation (Table 4). In the immature wheat forage, 83.3% of total N disappeared at a fractional rate of 19.9 %/hr which was greater ($P<.05$) than the second N pool, 16.7% of total N, which disappeared at 3.1 %/hr. For mature wheat forage, the two N pools were similar in size (i.e., 53 and 47% of total N) although the fractional rate of N disappearance from the more soluble N pool was 10 fold greater ($P<.05$) than the less soluble N pool (i.e., 16.03 vs 1.62 %/hr). Similar results were observed by Zorrilla-Rios et al. (1985) who indicated that 50 to 75% of total wheat forage nitrogen rapidly disappeared from the highly soluble pool at fractional rates of 13 to 28 %/hr. These data and those of Zorrilla-Rios et al. (1985) are consistent with the concept that degradation of wheat forage CP is rapid, and that large quantities of dietary N may fail to reach the small intestine because of the loss of ammonia-N that is not incorporated into microbial protein in the rumen. Consequently, performance of growing cattle on wheat pasture may be improved by supplementation with proteins of low ruminal degradability.

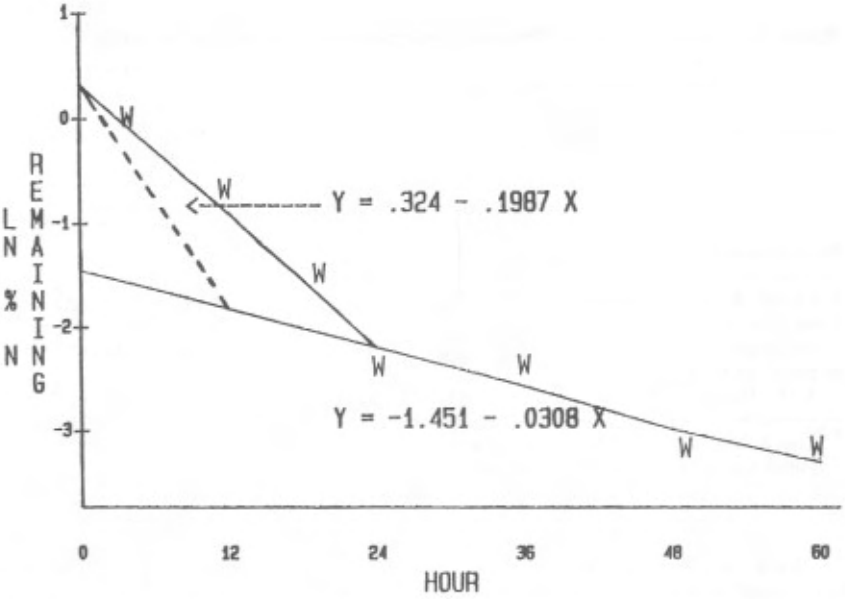

Figure 1. In situ nitrogen disappearance of two nitrogen pools in immature wheat forage.

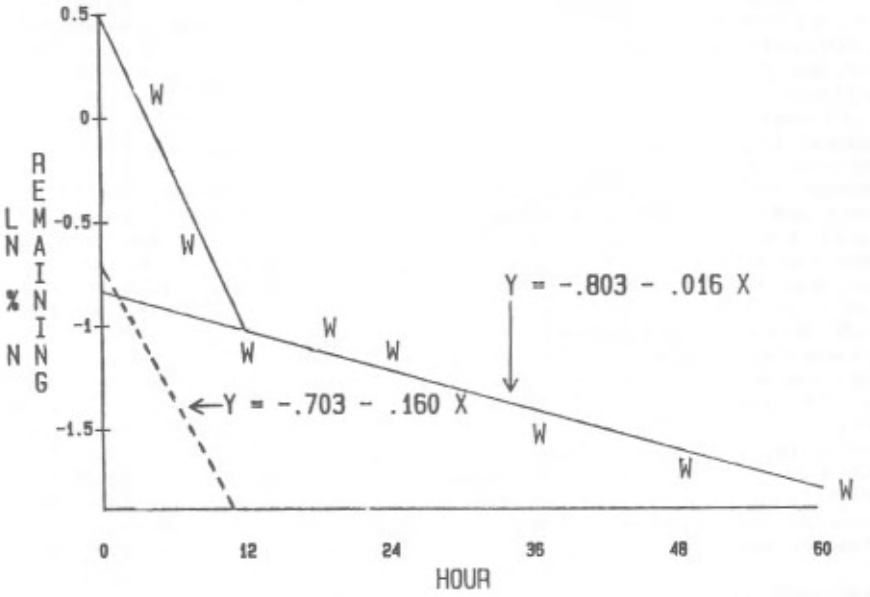

Figure 2. In situ nitrogen disappearance of two nitrogen pools in mature wheat forage.

Table 4. Wheat forage nitrogen disappearance bases on in situ ruminal measurements for steers grazing wheat pasture of two stages of maturity.

	Stage of maturity			
	Immature		Mature	
Measurement	4-24 hr	24-60 hr	4-12 hr	12-60 hr
Rate of N disappearance, %/hr	19.87[a]	3.08[b]	16.03[a]	1.62[b]
Time for half of N to disappear, hr	3.77[a]	28.54[b]	5.32[a]	46.80[b]
N pool size at 0 hr, % of total N	83.33[a]	16.67[b]	52.98[a]	47.02[a]

[ab]Row means within the same stage of maturity with different superscripts are different (P<.05).

Rate and extent of in situ ruminal disappearance of N of the protein supplements are shown in table 5. The main effect due to lasalocid did not affect (P>.10) rate of N disappearance. However, a significant lasalocid x protein supplement interaction was detected (P<.05) because of an effect of lasalocid with SBM only. Disappearance of N of SBM increased (P<.05) from 5.46 %/hr to 7.92 %/hr with lasalocid.

A significant protein supplement x forage maturity interaction (P<.05) for both rate and extent of N disappearance from the protein supplements was detected. Although rates of disappearance of N of CSM, CGM and FSM were similar for both forage maturities, SBM and MBM had different (P<.05) rates of digestion in each period. For SBM, the fractional rate of N disappearance (%/hr) was greater during the immature (7.59) than during mature (5.78) grazing periods. It is possible that solubility of SBM N may have been influenced by the change in rumen pH associated with increasing forage maturity. Fractional rate of N disappearance of MBM was greater during the mature (3.43 %/hr) than immature (1.89 %/hr) grazing period. Nonetheless, when the data were pooled across forage maturity, rate of N digestion was greatest for SBM (6.67 %/hr). Meat and bonemeal (2.66 %/hr) and CSM (2.37 %/hr) had intermediate values, while FSM (.85 %/hr) and CGM (.70 %/hr) had the lowest N disappearance (P<.01). Extent of N disappearance at 36 hr tended to parallel the rates of N disappearance with the exception of CGM. Although CGM was degraded at a rate similar to FSM, the extent of N disappearance was only 45% (P<.01) of FSM. This difference can be attributed to differences in N solubility. Initially, 27% of FSM N was present as soluble N while only 7.52% of CGM N was soluble (table 2). In addition, CGM is a glutinous material which tends to stick together when wet, resulting in less surface area exposed for ruminal digestion and consequently decreased N disappearance.

Experiment II

Fractional rate of passage of the Cr-mordanted supplements was similar (P>.05) for all protein supplements and averaged 4.91 %/hr as

Table 5. Rate and extent of in situ ruminal nitrogen disappearance of protein supplements in steers grazing wheat pasture of two stages of maturity (Experiment I).

Item	Stage of maturity	Protein supplement[a]					SEM[b]
		SBM	CSM	CGM	MBM	FSM	
Rate of disappearance, %/hr							
	Immature	7.59^{ch}	2.49^{d}	.53^{e}	1.89^{dh}	.86de	.47
	Mature	5.78^{ci}	2.26^{d}	.88^{e}	3.43^{di}	.84^{e}	.47
	Mean	6.67^{c}	2.37^{d}	.70^{e}	2.66^{d}	.85^{e}	.33
Extent, % at 36 hr							
	Immature	92.47^{ch}	68.61^{d}	21.71^{g}	57.23^{eh}	44.89^{f}	1.76
	Mature	82.55^{ci}	65.14^{e}	19.86^{g}	74.76^{di}	46.72^{f}	1.76
	Mean	87.57^{c}	66.87^{d}	20.78^{f}	66.00^{d}	45.80^{e}	1.25

[a]SBM = soybean meal, CSM = cottonseed meal, CGM = corn gluten meal, MBM = meat and bone meal, FSM = fishmeal.

[b]Standard error of the mean.

c,d,e,f,g,h,i Means in the same row with different superscripts are different ($P<.01$).

c,d,e,f,g,h,i Means in each column with different superscripts are different ($P<.01$).

shown in table 6. The similarity in passage rates might be attributable to a similar particle size distribution for the supplements and a common basal diet.

The parameters (i.e., a, b and c) of the exponential equation describing N disappearance in situ for CSMds, CSMm and MM are also presented in table 6. Fraction "a" of CSMm was 63% and 73% lower (P<.01) than that of CSMds and MM, respectively, while fraction "b" was 28% and 123% greater, respectively. This demonstrates that CSMds possesses a larger protein fraction that is more rapidly degraded and a smaller quantity of the more slowly degraded protein than CSMm. Fractional rate of ruminal N disappearance of fraction "b" was almost twofold greater (P<.01) for CSMds than either CSMm and MM (i.e., 8.65 vs 3.95 and 4.91 %/hr). If N disappearance of CSMds, CSMm and MM is expressed as the ln N remaining versus time, as in experiment I, the fractional rates of N disappearance would be 4.04, 2.71 and 1.18 %/hr, respectively. Of the N present in the protein supplements, approximately 90% was potentially degradable for the two CSM while only 67.7% was potentially degradable for MM. However, ruminal degradation of CSMds was about 20 percentage units greater (P<.01) than CSMm and MM. Consequently, greater amounts of N from supplemental CSMm and MM would be expected to pass to the small intestine. The increased temperature and pressure to which CSMm is exposed during processing as compared with CSMds may improve N utilization by increasing ruminal escape.

In conclusion, these data indicate that degradation of wheat forage CP is rapid. Zorrilla-Rios et al. (1985) concluded that the postruminal supply of wheat forage protein may limit animal performance. This suggests that supplementation with feeds of low ruminal protein degradation may improve weight gains. Of the feedstuffs investigated, CGM and FSM in experiment I and CSMm in experiment II appeared to be least resistant to ruminal degradation. Application of these results may be important in formulation of supplements for growing cattle grazing wheat and(or) small grain pastures if further studies indicate that stocker cattle performance is limited by flow of inadequate amounts of

Table 6. Parameters of an exponential equation describing N disappearance and extent of rumimal N degradability of CSMds, CSMm, and MM for steers grazing wheat pasture (Experiment II).

Item	Protein supplement[a]			SEM[b]
	CSMds	CSMm	MM	
Fraction a, %	33.34[c]	20.39[d]	35.74[c]	1.93
Fraction b, %	55.67[d]	71.47[c]	31.99[e]	3.36
Potentially degradable, %	89.01[c]	91.86[c]	67.72[d]	2.58
Rate of N disappearance, %/hr	8.65[c]	3.95[d]	4.91[d]	.87
Passage rate (k), %/hr	4.57[c]	5.20[c]	4.95[c]	.70
Ruminal degradability (RD), %	70.07[c]	50.70[d]	51.12[d]	2.17

[a]CSMds = cottonseed meal (direct solvent), CSMm = cottonseed meal (mechanical process), MM = meat meal.
[b]Standard error of the mean.
[c,d,e]Means in the same row with different superscripts are different (P<.01).

NAN to the small intestine. Alterations in flow of individual amino acids to the small intestine and subsequent effects on empty body protein synthesis and(or) forage intake may also be part of the mechanism whereby protein supplementation of growing cattle on wheat pasture improves performance.

Literature Cited

Lee, Robert W. 1984. Personal Communication.

Lee, Robert W. 1985. Bypass protein supplementation for cattle grazing wheat pasture. Kansas Cattle Feeders Day. Report of Progress 474. p. 7.

Ørskov, E. R. and I. McDonald. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agr. Sci. (Camb.) 92:499.

Zorrilla-Rios, J. et al. 1985. In situ disappearance of dry matter and nitrogen of wheat forage, corn gluten meal, cottonseed meal and soybean meal in steers grazing wheat pasture at two stages of maturity. Oklahoma Agr. Exp. Sta. Res. Rep. MP-117:169.