RUMINAL DIGESTION OF VARIOUS PROTEIN SOURCES

J.R. Barrio[1], A.L. Goetsch[2], D.C. Weakley[1] and F.N. Owens[3]

Story in Brief

The rate and extent of dry matter and nitrogen disappearance (DMD and ND) of various feedstuffs suspended in the rumen inside dacron bags was measured using steers fed a 20 percent (C) or a 60 percent (R) roughage diet. Eighteen different feedstuffs were ruminally incubated for 4, 12 and 24 hours. ND from soybean, cottonseed and linseed meals was more extensive at 12 and 24 hr of incubation with steers fed the R diet than with steers fed the L diet. But, diet did not influence disappearance of other feedstuffs. In situ ND at 4 hr of incubation was much greater than the soluble nitrogen content of certain feedstuffs including feather and meat meals, high moisture corn, oats and wheat. These findings indicate that with certain feedstuffs, fine particles were filtering through the pores in the dacron bag. With low protein feedstuffs, low nitrogen content caused technical problems in estimating ND. Extent of bacterial protein contamination of washed feed residues tended to be greater with the roughage diet but was minimal (<6 percent of nitrogen) with most feedstuffs.

Introduction

Protein supplements for ruminant animals are of special concern since they generally are expensive. Protein can have a marked influence on animal production and high bypass appears useful under some feeding conditions. Currently, feed manufacturers are interested in high protein feeds which possess a high degree of resistance to ruminal fermentation. Performance benefits are occasionally observed when a high bypass feed increases total duodenal flow of protein or if the amino acid balance of duodenal protein is improved when a bypass source of protein or amino acids is fed. Classes of ruminants which may benefit from increased bypass of feed protein include high producing lactating dairy cows and young, very rapidly growing calves. Further knowledge of the susceptibility of various protein sources to ruminal destruction is needed. This study was conducted to determine the effect of dietary concentrate level on in situ dry matter and nitrogen disappearance of 18 different feedstuffs.

Materials and Methods

Two Brahman crossbred steers (579 lb), fitted with ruminal cannulas (10.2 cm id), were used in a crossover experiment. Animals were penned individually and fed diets (Table 1) at 1.7 percent of body weight (dry matter basis) in four feedings at 6 hr intervals to avoid fluctuations in ruminal conditions. Periods were 18 days long, with ten days for adaptation and eight days for in situ incubations. Four, one-day incubation periods were used. One day separated each incubation period to minimize disturbance of ruminal digestion.

[1]Former Graduate Assistant [2]Research Associate [3]Professor

Table 1. Composition of diets, percent of dry matter.

Ingredient	Diets[a] 80(C)	40(R)
Prairie hay, chopped	20.0	60.0
Corn grain, rolled	75.4	26.2
Soybean meal	.0	9.9
Molasses	1.5	1.5
Urea	1.20	.54
Salt, trace mineralized	.30	.30
Limestone	.60	.0
Dicalcium phosphate	.30	1.00
Sodium sulfate	.30	.20
Potassium chloride	.40	.40

[a]Diets: Numbers refer to percentage of concentrate in diets.

Duplicate dacron bags containing the different substrates (Table 2) were incubated for 4, 12 and 24 hours in three of the four incubations and for 4 and 12 hours in the last incubation of each period. Bags containing hair curlers were used as blanks. When removed from the rumen, dacron bags were rinsed with tap water until the rinse water was clear and were dried at 100 C for determination of residual dry matter (DM). Bags plus feed residue contents were then analyzed for total nitrogen (N) content. DMD and ND were calculated and degree of microbial contamination, via nucleic acid content were determined.

Ruminal fluid samples, taken at times bags were inserted into the rumen, were measured for pH immediately, strained through cheesecloth, acidified and frozen. Later, samples were thawed and analyzed for ammonia nitrogen (NH_3-N) concentration.

Results and Discussion

Ruminal pH for the three sampling times was higher with the R diet (6.58) than with the 80 percent C diet (6.34), whereas NH_3-N was slightly lower (5.51 vs 6.91 mg NH_3-N/dl). Differences in pH due to diet were less than expected. The moderate intake level and the frequent feeding schedule that were employed may have decreased post-feeding fluctuations in pH. Frequent feeding also may have stabilized ruminal NH_3-N concentrations.

Rates of in situ disappearance of DM and N often are reported to be greater with roughage than concentrate diets. Factors thought to be involved include 1) effects of pH on protein solubility, 2) an alteration of fiber digestion through changes in microbial species and 3) altered enzyme production and activity. In this study, in situ DMD and ND after 4 hours averaged across feedstuffs, were greater for the R diet. However, ND at 24 hours was not affected by diet. Degree of microbial contamination of the residues was minor. For the feedstuffs tested, nucleic acid-N averaged only .75 percent of the feed N at 4 and 12 hours of incubation (Table 4). If nucleic acid-N represents 20

Table 2. Feedstuff composition.

Feedstuff	Dry matter %	Crude protein % of DM	Soluble protein[a] % of protein
PROTEIN SUPPLEMENTS			
Corn gluten meal	91.1	63.0	12.1
Cottonseed meal (a)	93.7	44.2	17.9
Cottonseed meal (b)	92.4	44.3	24.7
Feather meal	91.2	85.5	13.3
Fish meal	93.1	73.5	24.3
Linseed meal	89.7	40.2	38.7
Meat meal (a)	96.1	52.7	20.9
Meat meal (b)	94.8	52.2	42.0
Soybean meal (a)	89.0	50.2	27.2
Soybean meal (b)	88.2	54.1	24.2
Sunflower meal	92.8	31.0	37.5
ENERGY FEEDS			
Corn grain, cracked	89.3	9.2	11.7
Corn grain, rolled	86.4	9.2	40.0
Corn grain, high moisture	81.2	8.7	31.8
Oats, rolled	91.2	12.8	16.9
Sorghum grain, milo, ground	87.2	9.3	26.5
Wheat, ground	85.6	15.0	37.9
ROUGHAGES			
Alfalfa hay, chopped	91.4	20.4	41.2
Corn silage	36.5	9.0	89.0
Prairie hay, chopped	93.1	4.3	42.1
Sorghum silage	46.4	7.0	60.3

[a] In .15 N NaCl solution.

Table 3. Effects of diet on dry matter and nitrogen disappearance averaged across feedstuffs.

Measurement	Incubation Time	Concentrate percentage 80(C)	40(R)
Dry matter disappearance	4 h	29.1	29.6
	12 h	36.7	39.4
	24 h	47.0	46.7
Nitrogen disappearance	4 h	47.9	44.7
	12 h	50.0	50.2
	24 h	54.6	32.1
Nucleic acid-N % of residual N	4 h	.64	.73
	12 h	.57[a]	1.07[b]

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

Table 4. Effect of dietary concentrate level on DMD and ND of protein supplements.

Diet, % concentrate		Extent (%) of disappearance			
		Dry matter		Nitrogen	
Feedstuff	Time, h	80(C)	40(R)	80(C)	40(R)
Corn gluten meal	4	17.6	15.3	18.4	14.8
	12	23.1	22.2	18.9	21.5
	24	27.6^a	25.0^b	19.8	17.0
Cottonseed meal (a)	4	30.2	29.7	31.5	32.0
	12	38.9^a	41.1^b	38.9^c	42.1^d
	24	46.2	49.7	43.8	47.2
Cottonseed meal (b)	4	27.2	27.4	33.3	36.4
	12	40.2	40.6	49.9	43.8
	24	50.7^c	57.8^d	58.3	62.9
Feather meal	4	19.2	18.4	32.9	30.0
	12	21.7	21.3	32.6	35.6
	24	23.0	23.4	33.3	34.6
Fish meal	4	20.5	20.0	37.0^a	33.7^b
	12	25.5	23.3	39.0^c	41.0^d
	24	25.5	23.4	47.0	47.9
Linseed meal	4	34.5	35.4	52.0	38.7
	12	45.9^a	52.5^b	55.5	65.7
	24	55.0^a	63.2^b	68.2^c	76.9^d
Meat meal (a)	4	32.9	32.1	44.1	47.3
	12	37.7	35.2	49.3	49.3
	24	39.1	32.4	54.4^c	47.7^d
Meat meal (b)	4	36.9^c	54.7^d	62.2^a	73.7^b
	12	47.4	46.5	71.0	71.3
	24	52.2^a	44.7^b	71.8	72.7
Soybean meal (a)	4	33.3^a	36.5^b	27.7^a	32.1^b
	12	45.3^a	57.9^b	40.4	51.4
	24	61.1^a	80.3^b	54.9^a	82.3^b
Soybean meal (b)	4	32.4^a	36.5^b	25.9^a	30.9^b
	12	45.6^a	57.9^b	39.1^a	51.5^b
	24	65.9	72.8	61.5^a	76.1^b
Sunflower meal	4	30.9	35.4	47.4^a	58.0^b
	12	42.6^a	48.0^b	64.3	67.5
	24	51.8	48.7	76.4	71.6

[a,b] Means in a row with different superscripts differ ($P<.05$).
[c,d] Means in a row with different superscripts differ ($P<.10$).

percent of total microbial N, the degree of contamination of residues with microbial N averaged only 4 percent of residual N.

Dry matter and nitrogen disappearance values after 4, 12 and 24 hr of ruminal incubation for all substrates illustrate the variability of in situ disappearance among feedstuffs (Tables 4, 5 and 6). Disappearance of nitrogen from soybean meal (SBM), cottonseed meal (CSM) and linseed meal was greater at 12 and 24 hours of incubation with steers fed the R diet than with steers fed the C diet. But diet did not greatly influence disappearance of other feedstuffs.

In situ loss at 4 hours of incubation was much greater than the soluble nitrogen content of certain feedstuffs, including feather meal, meat meal, high moisture corn, oats and wheat. This is probably due to

Table 5. Effect of dietary concentrate level on DMD and ND of energy feedstuffs.

Diet, % concentrate		Extent (%) of disappearance			
		Dry matter		Nitrogen	
Feedstuff	Time, h	80(C)	40(R)	80(C)	40(R)
Corn, cracked	4	3.7	3.6	28.1	18.3
	12	7.5^{a}	11.4^{b}	23.4	19.2
	24	18.6	24.0	28.5^{a}	1.7^{b}
Corn, ground	4	30.7	30.9	40.1	42.2
	12	38.5	41.7	39.9	41.6
	24	64.2	66.2	50.0^{a}	26.1^{b}
Corn, high moisture	4	30.0	28.6	39.7	45.3
	12	40.1	43.4	29.4	54.2
	24	63.2	68.7	39.7^{c}	10.2^{d}
Milo, ground	4	24.7	24.1	25.4	33.7
	12	34.0	36.6	35.9	33.6
	24	53.9	52.0	47.0	32.1
Oats, rolled	4	30.0	29.6	71.8	70.6
	12	38.7	38.0	75.6	72.1
	24	38.1	40.2	77.5	65.4
Wheat, ground	4	76.6^{a}	60.0^{b}	95.5^{a}	68.6^{b}
	12	80.8	75.4	96.8	89.7
	24	84.5	81.6	103.2	92.7

[a,b] Means in a row with different superscripts differ ($P<.05$).
[c,d] Means in a row with different superscripts differ ($P<.10$).

Table 6. Effect of dietary concentrate level on DMD and ND of forages.

Diet, % concentrate		Extent (%) of Disappearance			
		Dry matter		Nitrogen	
Feedstuff	Time, h	80(C)	40(R)	80(C)	40(R)
Alfalfa hay	4	29.1^{a}	31.1^{b}	49.4	42.3
	12	37.4^{a}	48.6^{b}	50.1	61.5
	24	56.2	56.4	77.5	73.3
Corn silage	4	36.5	37.4	108.7	96.7
	12	43.1	43.0	80.4	90.8
	24	53.6	31.1	105.6	-27.8
Prairie hay	4	10.4	10.1	66.1	36.3
	12	12.1	12.7	38.7^{a}	-12.0^{b}
	24	19.8	17.2	24.1	-120.5
Sorghum silage	4	22.9	24.3	68.9	57.4
	12	28.6	27.3	65.8	65.1
	24	35.8	11.1	3.6	-151.

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

rinsing of fine particles out of the dacron bags. These findings suggest that with certain feeds, in situ disappearance at 4 hr would overestimate digestion of N. Also, with low protein feedstuffs, low nitrogen content caused technical problems in estimating nitrogen disappearance. Nevertheless, N disappearance appeared to considerably exceed dry matter disappearance with wheat and oats whereas with milo and corn, DMD exceeded ND.

ND paralleled DMD for most feedstuffs. Low ND for certain feeds (corn gluten meal, feather meal, fish meal) is associated with very low DMD of these feedstuffs. Inhibiting disappearance of DM should automatically increase protein bypass with many feedstuffs.

With SBM, CSM and linseed meal, N loss closely paralleled DM loss. With these feedstuffs, disappearance of protein appeared to be linked to or limited by removal of DM. For these same feedstuffs, a relationship of ND to concentrate level was detected. This relationship may be an indirect effect of concentrate level on rate of digestion of dry matter or cell walls. Extent of ruminal protein digestion may differ with concentrate level when protein is associated with fibrous cell walls.

Finally, with some feedstuffs, including meat meal, sunflower meal, wheat and oats, the percentage of N disappearance considerably exceeded the percentage loss of DM. This suggests that there are several types of protein in such feeds and that portions are solubilized or digested independent of DM. This would lower the protein content of the residual DM in the rumen. The above relationships may be associated with location of protein in various cell components--cell contents versus cell walls. In addition, level of feed intake would influence both ruminal residence time and extent of cell wall digestion in the rumen. Consequently, both concentrate level and feed intake level are needed to predict bypass values for each feedstuff which will be applicable to a variety of different ruminal conditions.