RUMINAL ESCAPE, TURNOVER RATE AND IN SITU DISAPPEARANCE OF SOYBEAN MEAL PROTEIN IN LACTATING COWS FED DIETS AT TWO CONCENTRATE TO FORAGE RATIOS

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Story in Brief

Diets with two concentrate to forage ratios supplemented with either urea or soybean meal were fed to six lactating dairy cows equipped with duodenal cannulas. Diets contained 65 or 35 percent of dry matter as concentrate with the remainder being sorghum silage and alfalfa hay. With 65 and 35 percent concentrate diets 46 and 18 percent of the soybean meal protein fed escaped ruminal digestion. Post-ruminal digestion of nitrogen, as a percent of that reaching the small intestine, averaged 62 to 75 percent. Ruminal passage rates for soybean meal were similar (8.7 vs 8.3 percent/hour) while ruminal degradation rates (percent/hour) for soybean meal nitrogen were 5.3 and 10.7 for the 65 and 35 percent concentrate diets, respectively. Predicted ruminal escape of soybean protein, based on these passage and degradation rates and nitrogen solubility (9.8 percent) were 56.1 and 39.3 for the 65 and 35 percent concentrate diets. Ruminal escape of soybean protein increased as concentrate level increased due to less rapid microbial digestion in the rumen with the higher concentrate ration.

(Key Words: Soybean Meal, Nitrogen, Escape, Ruminants.)

Introduction

Escape values for soybean meal (SBM) nitrogen range from 10 to 61 percent (NRC, 1985). Most of these values have been determined with sheep or cattle fed roughage diets at low levels of feed intake. Only one dairy cow trial (Goetsch and Owens, 1985) has estimated ruminal escape (35 percent) but their calculations were based on an assumed escape value of 60 percent for corn grain protein. Hence, this value may not apply to more typical dairy diets. Using a mean escape value to formulate diets for dairy cattle remains tenuous due to the variation in escape values. Further, extent of protein degradation in the rumen is not constant but varies with certain dietary factors (dry matter intake and feed particle size) which in turn can alter ruminal pH, microbial activity and passage rate (Weakley et al., 1983). Relative importance of these factors has not been measured in lactating cows.

The objective of this study was to directly estimate the proportion of soybean meal protein which escaped ruminal degradation with two levels of dietary roughage and determine the effects of roughage level on ruminal digestion and turnover rates.

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Materials and Methods

Two months prior to calving, six dairy cows were surgically prepared with T-type cannulae in the duodenum proximal to the pancreatic and bile ducts. Cows were rotated among the four diets which consisted of two concentrate to forage ratios of 65:35 and 35:65 with protein or protein equivalent, from either urea or SBM. Diets were each fed for 2-week periods with data being collected the final 5 days of each period.

Diets consisted of a concentrate mixture, alfalfa hay and sorghum silage (Table 1). The concentrate mixture consisted of ground corn plus either soybean meal or urea plus corn starch (Table 2) so that the percentage of corn remained constant between test diets. Formulation of diets in this manner permitted soybean meal escaping rumen degradation to be estimated by difference after subtracting microbial protein from total duodenal nitrogen.

The complete mixed diets were fed to cows at 0400 and 1800 hours each day. Chromic oxide was included as an indigestible flow marker, however indigestible neutral detergent fiber (INDF) was used as a marker to calculate duodenal digesta flow of organic matter and nitrogen. Samples of the concentrate, sorghum silage and alfalfa hay and feed refused were collected each week and analyzed for dry matter and protein. Milk yields were recorded twice daily at 0600 and 1800 hours. Milk samples were collected for four consecutive milkings each week, composited, and analyzed for milk fat and total protein.

One rumen fistulated cow randomly assigned to a treatment sequence of the diets was used for isolation of bacteria which was analyzed for total nitrogen (N) and for nucleic acid-N. This cow was also used to evaluate rate of ruminal digestion of SBM from dacron bags suspended in the rumen.

On day 5 of each collection period, 250 g of soybean meal labeled with ytterbium (Yb) were fed to each intestinally cannulated cow. Starting 12 h post feeding, approximately 400 ml of duodenal digesta were collected every 12 h for 2 d. Duodenal samples were analyzed for Yb. On day 7 of the collection period, approximately 250 ml of rumen fluid were collected by stomach tube from each intestinally cannulated cow for ammonia determination.

Table 1. Composition of diet used in SBM nitrogen ruminal escape experiment.

	Percent concentrate diet			
	65		35	
Item	SBM	U	SBM	U
	% dry matter			
Ingredient				
Sorghum silage	17.5	17.5	32.5	32.5
Alfalfa hay, chopped	17.5	17.5	32.5	32.5
Concentrate (Table 2)	65	65	35	35
Crude protein	14.6	12.9	14.5	12.4

Table 2. Composition of concentrate portion of diets used in SBM nitrogen ruminal escape experiment.

	Percent concentrate diet			
	65		35	
Item	SBM	U	SBM	U
	% dry matter			
Ingredient				
Corn, ground	68.6	68.6	58.8	58.8
Soybean meal	17.6	----	27.4	----
Cornstarch	----	15.6	----	25.0
Cottonseed hulls	3.9	3.9	3.9	3.9
Urea	----	2.0	----	2.4
Molasses, cane	4.9	4.9	4.9	4.9
Dicalcium phosphate	2.0	2.0	2.0	2.0
Salt, trace mineralized	1.0	1.0	1.0	1.0
Chromic oxide	2.0	2.0	2.0	2.0
Crude protein	16.2	13.7	20.0	14.2

Results and Discussion

Mean ruminal passage rates for soybean meal labeled with ytterbium were 7.9 to 8.7 percent/h (Table 3). These means are higher than the 4.9 percent/h for lactating dairy cows ad libitum fed a basal diet of 60 percent alfalfa hay and 40 percent concentrate (Stern et al., 1983) but similar to estimates of 6.0 to 7.7 percent/h for grain in the rumen of lactating cows fed diets containing 50 percent alfalfa hay diets (Eickelberger et al., 1985) and somewhat greater than the 5.8 percent estimated for SBM with a 50 percent concentrate, 30 percent corn silage diet (Erdman, 1981). Passage rate in the present trial tended to be slightly higher with the high concentrate than with low concentrate diet.

Table 3. Rates of passage of soybean meal and of digestion in dacron bags suspended in the rumen.

			Percent concentrate in diet			
			65		35	
Feed	Component	Rate measurement	SBM	U	SBM	U
			%/h			
SBM	Yb	Passage	8.7	8.6	8.3	7.9
	DM	Digestion	6.7	6.3	5.3	10.6
	N	Digestion	5.3	3.2	10.7	6.0
Alfalfa hay	DM	Digestion	1.3	1.0	1.1	1.5
	N	Digestion	1.8	2.1	2.6	1.3
Sorghum silage	DM	Digestion	0.4	0.3	1.3	1.5
	N	Digestion	2.0	1.0	2.6	2.0

Rates of nitrogen disappearance in the rumen for soybean meal (Table 3) tended to be lower when the high concentrate diet was fed. Rates of dry matter digestion of alfalfa hay and sorghum silage also tended to be higher with the higher roughage diet. Protein content and diet composition presumably altered the ruminal flora or fauna so that rate of ruminal digestion was altered. Ruminal digestion rate for plant proteins previously has been reported to be greater with a high roughage than with a high concentrate diet (Weakley et al., 1983).

Rate of protein digestion from soybean meal tended to be higher if SBM was included in the diet with the 65 percent concentrate diet. Loerch et al. (1983) reported that nitrogen digestion from SBM in situ was greater with SBM in the diet. This could reflect microbial adaptation to degrade SBM or other changes in microbial activity in the rumen which increased rate of destruction of all protein sources.

Ruminal escape of N was predicted from these data using the equation:

$$E = k_p/(k_p + k_d);$$

where K_p and k_d are fractional passage and digestion rates. Using values from Table 3 as applied to total N in SBM, predicted escape values are 62 and 44 percent for the 65 and 35 percent concentrate diets. If soluble N of SBM is deducted prior to calculations, predicted escape values become 56 and 39 percent, respectively. Since rate of passage (k_p) was unchanged, the entire difference in predicted escape is due to a faster rate of digestion with the higher roughage diet.

In Vivo Trial

Mean dry matter (DM) intake ranged from 35.7 to 40.5 lb/day for the treatment groups (Table 4). DM intake was highest ($P<.01$) for cows receiving the low concentrate diet with urea. DM intake may have increased to compensate for the lower crude protein content and caloric density of this diet. Body weight gain tended to be greater with the high concentrate diets. Ruminal ammonia levels tended to be higher with the lower concentrate diets and with soybean meal in the diet. Added corn starch, being rapidly and completely digested, may have increased ammonia utilization by ruminal microbes and decreased ammonia concentrations in the rumen.

Mean daily milk yield, milk fat and milk protein for the experimental diets ranged from 42.5 to 50.9 lb, 3.7 to 3.8 percent and 3.4 to 3.8 percent (Table 4). Mean milk yield tended to be higher with the high concentrate diets reflecting the higher protein and caloric density of these diets. Fat-corrected milk production was higher when cows were fed the 65 percent than when fed the 35 percent concentrate diet ($P<.02$).

Duodenal flow of OM was variable across diets ($P>.37$) and non-microbial N flow reflected differences in OM intake (Table 5). Post-ruminal digestion, as a percentage of duodenal flow, was greater with the 65 percent concentrate diet ($P<.01$). Total tract OM digestion, based on chromic oxide as an indigestible marker, tended to be higher for the high concentrate diets. Total tract digestibilities were lower than anticipated for these diets as compared with values reported by Goetsch and Owens (1985).

Ruminal digestion of OM averaged 48 percent, higher than many values reported in previous studies. OM digestion in the stomach as a percentage of OM intake in other studies has generally ranged from 27 to 48 percent. In most studies with intestinally-cannulated cows,

Table 4. Responses of cows fed experimental diets.

Item	Percent concentrate diet			
	65		35	
	SBM	U	SBM	U
Dry matter intake, lb/day	36.6	35.7	36.8	40.5
Protein, % of DM	14.9	13.3	15.7	13.6
Total protein intake, lb/day	5.44	4.76	5.77	5.53
Weight change, lb/day	0.1	0.1	0.0	0.0
Ruminal NH_3-N, mg/dl	8.6	5.7	11.7	7.8
Production				
Milk, lb/day	50.9	46.3	43.6	42.5
Fat, %	3.7	3.7	3.7	3.8
Protein, %	3.5	3.4	3.7	3.7
FCM[a]	47.8	44.3	41.2	41.4

[a]FCM = 0.4 x lb milk/day + 15 x lb fat/day.

Table 5. Organic matter digestion in cows fed diets at two concentrate to forage ratios with or without SBM.

	Percent concentrate in diet			
	65		35	
	SBM	U	SBM	U
Organic matter intake, g/d	15372	15162	15316	16984
Leaving abomasum, g/d				
Total	8205	6670	7461	8913
Non-microbial	5956	4892	5615	6498
Ruminal digestion, %				
Unadjusted	46.0	53.7	49.1	42.6
Adjusted[a]	60.7	65.8	61.8	58.1
Feces, g/d	6362.6	6812.6	7788.1	8382.7
Post-ruminal digestion, % of input	60.3[b]	53.7[bc]	42.7[cd]	48.9[d]
Total tract digestion	59.5	55.6	48.6	52.1

[a]Adjusted for microbial contribution.
[bcd]Means in a row with different superscripts differ ($P<.05$).

daily dry matter intake has been restricted to 12 to 22 lb. Such intakes are low for lactating dairy cows. Many studies have shown that as feed intake increases, the flow of digesta through the forestomachs increases which reduces the portion of OM digested in the rumen.

Nitrogen flow at the duodenum and digestibility were calculated based on INDF as the digesta flow marker (Table 6). To determine the

Table 6. Nitrogen (N) digestion in cows fed diets at two concentrate to forage ratios with or without SBM.

Item	Percent concentrate in diets			
	65		35	
	SBM	U	SBM	U
Intake, g/d				
Total	374.7	321.5	400.7	365.6
SBM	142.9	0	123.3	0
Leaving abomasum, g/d				
Total	393.3	272.6	336.1	374.5
Microbial N	206.9	154.4	163.1	204.1
Ammonia N	22.8	20.3	21.3	41.1
Non-ammonia, non-microbial	163.6	98.0	151.6	129.4
Ruminal digestion, %				
Unadjusted	- 1.0	-17.2	-15.6	- 1.0
Adjusted[a]	59.2	69.7	62.4	64.6
Dietary N escape, excluding urea	43.7	43.2	37.8	44.1
SBM escape, %	45.9	---	18.0	---
Escape of non-SBM protein	42.3	43.2	46.7	44.1
Microbial efficiency, g N/kg OM	24.1	17.4	18.7	23.2
Feces, g/d	192.4	184.6	232.4	233.1
Post-ruminal digestion, % of input	74.8	69.4	62.2	66.6
Total tract digestion, %	52.5	46.5	43.8	43.7
Expected total tract N digestion, %[b]	69.0	67.4	70.6	68.1

[a]Adjusted for microbial and ammonia N.
[b]Calculated as: % digestible protein = (.9(% CP)-3)/% CP.

amount of soybean meal escaping ruminal degradation, urea plus corn starch was substituted for soybean meal at each concentrate level. To help prevent urea toxicity, total N in the urea diets was lower than in the SBM diets but enough urea was added to the diets to maintain adequate N for microbial synthesis. Based on composition of bacteria isolated from rumen fluid of the cow fed the experimental diets, N levels appeared to be adequate. Both chemical composition and microbial efficiency (g N per kg OM truly digested in the rumen) were not significantly altered by diet ($P>.51$). Bacterial efficiencies were similar to those reported by Goetsch and Owens (1985).

Non-ammonia non-microbial nitrogen passage to the duodenum tended to be greater with dietary SBM and with the 65 than the 35 percent concentrate diets. This is due to the increase in dietary protein escaping degradation in the rumen. Based on the differences in N flow leaving the abomasum between diets supplemented versus not supplemented with SBM, 45.9 percent and 18.0 percent of the dietary SBM protein escaped ruminal degradation with the 65 and 35 percent concentrate diets, respectively. Goetsch and Owens (1985) calculated soybean protein bypass to be 35 percent with dairy cows fed a 60 percent concentrate diet at 2.9 percent of body weight daily. These values are much higher than the 20 and 14 percent escape values reported by Weakley (1983) for 80 and 40 percent concentrate diets. He assumed ruminal escape of corn protein to be 60 percent for calculation purposes, where-

as in this trial ruminal escape of soybean protein was estimated directly rather than by replacement of corn protein in the diet. Zinn and Owens (1983) reported SBM bypass values of 43 and 24 percent with 80 and 40 percent concentrate diets, again assuming that corn protein escape was 60 percent. In our study, decreasing concentrate level from 65 to 35 percent decreased ruminal escape of SBM nitrogen by 28 percentage units or 61 percent. By difference, bypass of the non-soybean meal, non-urea fraction of the diet for the four diets was 42.3, 43.2, 46.7 and 44.1 percent. If escape of protein from corn grain had been 60 percent, escape of protein from non-corn, non- SBM sources (silage plus hay) calculates to be 23.0, 25.0, 43.3 and 39.8.

Most previous ruminal escape values for SBM have been confounded by other dietary protein sources. Though our escape values differ from those reported from other studies, our values are more direct estimates of ruminal escape at two concentrate to forage ratios than have previously been determined and are supported by nitrogen disappearance measurements from dacron bags. Few escape estimates are available for high-producing cows fed diets varying the forage to concentrate ratios at high levels of dry matter intakes. Based on results from this trial, using one single, constant value for ruminal escape of dietary soybean meal is imprecise. Escape values for protein sources to be used in formulating diets should be adjusted for concentrate level and feed intake level.

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