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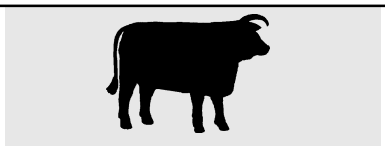

Effects of Cull Beans, Sunflower Meal, and Canola Meal as Protein Supplements to Beef Steers Consuming Grass Hay on In Situ Digestion Kinetics[1]

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Abstract

*Two ruminally cannulated steers were used in an in situ incubation study to test the effects of raw cull Great Northern beans (*Phaseolus vulgaris*), canola meal, and sunflower meal on rate and extent of digestion of forage DM, NDF, ADF, and N and to compare the DM and N digestibilities of the supplements. Steers were allowed ad libitum access to medium quality grass hay and were assigned in each of five periods to one of five supplemental treatments. The five treatments included: 1) unprocessed Great Northern beans to supply 182 g/d CP (GNB); 2) canola meal to supply 182 g/d CP (CM); 3) a mixture of Great Northern beans and sunflower to each supply 91 g/d CP (MIX); 4) sunflower meal to supply 182 g/d CP (SFM+); and 5) sunflower meal to supply 91 g/d CP (SFM–). Each period consisted of a 7-d adaptation period, 3-d intake period, and 4-d incubation period. Two bags of supplement, two bags of forage, and two blanks were incubated for 0, 4, 8, 12, 18, 24, 36, 48, 72, or 96 h. Treatment had no effect on rate, extent of digestion, or discrete lag time of forage DM, NDF, or ADF (P>0.10). Compared with the SFM+ treatment, forage N degraded at a faster rate when steers were on the GNB (P=0.06), CM (P=0.02), or SFM– (P=0.02) treatments. Forage N in the MIX treatment degraded slower than that in the GNB treatment (P=0.03). No differences (P>0.10) were detected for forage N lag time or extent of digestion. There were no differences in the rate of digestion of supplement DM or N (P>0.80), but canola meal had a greater extent of supplement DM degradation than the sunflower meal from the SFM+ treatment (P=0.13). When supplemented to medium quality hay diets, Great Northern beans, canola meal, or a mixture of Great Northern beans and sunflower meal had similar effects on in situ forage digestion kinetics. Anti-nutritional factors in the beans did not appear to alter rumen digestion of the tested forage.*

(Key Words: *Phaseolus vulgaris*, Canola Meal, Sunflower Meal, Digestion.)

Introduction

Supplementing protein to ruminants fed low quality forage has been shown to increase protein and fiber digestibility (4, 7), which can help minimize the loss of BW and condition during the winter months (5). Many producers in the Northern Great Plains desire low-cost, available protein sources to supplement cows grazing winter range. Sunflower meal, canola meal, and Great Northern beans (*Phaseolus vulgaris*) are often available and economical sources of protein as compared with commercial supplements.

Sunflower meal has been shown to increase DM digestibility of low quality forage (6). Canola meal has been associated with depressing NDF and ADF digestibility (16), and increasing N and energy digestibilities (14). Raw beans contain lectins and enzyme inhibitors that can interfere with digestive enzymes and damage

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the intestinal brush border (3). Feeding raw beans to ruminants on feedlot diets has reduced performance and caused diarrhea (17, 18); however, supplementing raw Great Northern beans to cows grazing dormant winter range has been shown to be comparable with sunflower meal, despite palatability problems with the beans (13). The effects of feeding raw cull beans on forage digestion in the rumen have not been investigated.

The objectives of this study were to determine the effects of supplemental sunflower meal, Great Northern beans (*Phaseolus vulgaris*), a mixture of beans with sunflower meal, and canola meal on rate and extent of forage nutrient digestion in the rumen and to compare in situ digestibility of DM and N in the supplements.

Materials and Methods

Two mature, ruminally fistulated steers (average, 726 kg) were used in a randomized complete block design to test five treatments over five periods (two animals per treatment) in an in situ incubation study at Colorado State University's Metabolic Laboratory. Treatments were designed to supply 182 g/d CP, except for the negative control, which supplied 91 g/d CP. Treatments included unprocessed Great Northern beans (GNB), canola meal (CM), a mixture of Great Northern beans and sunflower meal to each supply one-half of the 182 g/d CP (MIX), sunflower meal as a positive control (SFM+), and sunflower meal as a negative control (SFM–). The sunflower meal and canola meal were fed in pelleted form with the canola meal pellet including 14% cottonseed meal to make a pellet that would not crumble. The beans were fed as whole cull beans. The nutrient composition of the Great Northern beans, sunflower meal, and canola meal is shown in Table 1. The composition of these supplements did not differ between periods, but measured CP values were higher than expected CP values used to calculate the amount of supplement to feed. Therefore, the actual daily CP intakes for the five treatments were GNB, 219 g; CM, 205 g; MIX, 218 g; SFM+, 215 g; and SFM–, 107 g.

TABLE 1. Nutrient composition of cull Great Northern beans, pelleted sunflower meal, and pelleted canola meal (contained 14% cottonseed meal) fed to mature rumen fistulated steers consuming medium quality grass hay.

Item	Great Northern beans	Sunflower meal	Canola meal
DM, % as fed	89.7	90.5	90.6
CP, % DM	25.2	33.5	41.4
NDF, % DM	41.3	40.6	33.2
ADF, % DM	5.4	26.3	18.0

Each of the five periods consisted of a 7-d adaptation period and a 3-d forage intake period followed by a 4-d incubation period. During each 14-d period, the steers were allowed ad libitum access to medium quality mixed grass hay (Table 2) fed twice daily at 0700 and 1500 h and were supplemented at 0700 h each morning with one of the five protein supplements. Protein supplements were randomly assigned to steer within period, as each steer received each supplement one time. Five days of supplemental diets were preweighed at one time and stored in labeled containers. Samples were taken of the supplements at this time and added to a labeled composite. Forage samples were also taken every 5 d and added to a labeled composite.

Samples of the forage and each supplement were ground to pass a 2-µm screen in a Wiley Mill, and 5 g ground sample were then added to 10-cm × 20-cm Dacron bags (pore size, 50 mm) and sealed shut with a heat sealer. Blanks were prepared by folding one-half of a Dacron bag into a blank bag and heat-sealing it shut. The bag was placed inside the blanks to provide surface area for contaminate attachment comparable with that provided by the 5 g feed. Two bags of forage, two bags of the supplement that the animal was consuming, and two blanks were prepared for each removal time. When an animal was on the MIX treatment, supplement bags contained a mixture of sunflower meal and Great Northern beans in the same percentage as fed to the animal. Samples of the forage and supplement that were used in the bags were collected for future analyses. The bags for each removal time were labeled and attached to a rubber stopper that

TABLE 2. Nutrient analyses of mixed grass hay fed to beef steers in confinement during an in situ trial for each of five periods.

	Period				
Item	1	2	3	4	5
DM, % as fed	92.7	92.2	92.3	89.7	92.6
CP, % DM	7.9	8.3	8.1	8.3	9.0
NDF, % DM	70.3	70.9	69.2	69.0	67.7
ADF, % DM	37.5	36.1	35.9	36.5	34.3

had a swivel clip attached. All of the stoppers were then clipped onto a rubber tube with a weight attached at one end to keep the bags submerged in the ruminal fluid. On d 10 of each period, at 0700 h, bags were put in the rumen of each steer. One set of bags was immediately labeled as 0-h bags and placed in the freezer, as these were used to determine the soluble residue removed because of washing and handling. The appropriate bags were then removed at 4, 8, 12, 18, 24, 36, 48, 72, and 96 h.

Upon removal, rumen bags (stoppers included) were frozen at –20°C until the completion of the time period. When the full set of bags from a period had been frozen hard for at least 24 h, they were allowed to thaw overnight in preparation for washing. Each stopper was then clipped onto a metal basket that sat inside of a plastic wash tub with cold tap water running through it. The basket was attached to a pump shaft that raised and lowered the basket to add agitation to the bags. The bags were washed for 24 h, removed from the stoppers, and hand-rinsed to remove material remaining at the site of attachment to the stopper. The bags were dried for 64 h at 60°C, allowed to air equilibrate, and weighed for residual DM. Both forage and supplement residue were analyzed for N using the combustion method (1). Forage samples were analyzed for NDF and ADF using the Ankom$^{200/220}$ fiber analyzer (8; manufactured by Ankom Technology Corp., Fairport, NY). All samples of feed used in the in situ bags and composite feed samples were analyzed for DM, CP, NDF, and ADF by the methods described previously.

Data were fit to a nonlinear regression model in SAS® (15) using proc NLIN. The model used to calculate nutrient digestion kinetics was that described by Mertens and Loften (9): $P = D_0e^{-k(t-L)} + U$ when $t > L$, and $P = D_0 + U$ when $t < L$, where P = percentage of nutrient remaining after time t; D_0 = potentially digestible fraction; k = digestion rate constant; L = discrete lag time; and U = indigestible fraction. The kinetics data were then analyzed using the GLM procedure of SAS® (15), with treatment and period as the class variables (period, corresponding to each 14-d period, was the blocking factor). Intake measurements (as calculated during the 3-d intake period) were expressed as a percentage of BW and analyzed using the GLM procedure, with treatment and animal as the class variables. Means were compared using a priori contrasts with overall *F* protection ($P<0.05$). Contrasts included the GNB, CM, and SFM– compared with the SFM+ treatment, and the MIX treatment compared with the GNB treatment.

The residue in each in situ bag was adjusted for DM contamination using the blanks incubated and removed with that bag. Approximately 8% of the blanks was not used in adjusting DM values because of extreme variation (over 200%) from the average of the other blanks incubated for the same period of time. The readily soluble pool for each nutrient was subtracted from each observation by assuming that the soluble pool was that removed by the washing and handling of the 0-h bags. Therefore, the actual pools being modeled were assumed to be the B1 and B2 carbohydrate pools and the B2 and B3 protein pools as described by NRC (12). The kinetic estimates reported do not include the soluble pool.

One of the steers used in the study was reluctant to consume the cull beans offered in the GNB treatment. Intake of the beans improved when laced with corn syrup, yet the steer rarely consumed 100% of the offered supplement. Any beans refused during the period were placed directly in the rumen of the steer via the rumen fistula. Because beans appeared to be in whole form in the rumen of steers consuming beans orally, the addition of beans directly into the rumen was assumed to be analogous to oral consumption. The other steer seemed to have an aversion to the canola meal, and it was laced with small amounts of corn syrup for the first 3 d of the adaptation period. There were no refusals of the canola supplement after 3 d. The amount of corn syrup used to lace the supplements was very small (less than 0.5% of daily intake), as rumen digestion was not likely affected by this practice.

TABLE 3. The effect of varying protein supplements to steers in confinement on the rate of in situ forage degradation of the potentially degradable fractions (soluble pool removed) of DM, NDF, ADF, and N[a].

	Treatment					
Item	**GNB**	**CM**	**MIX**	**SFM+**	**SFM–**	**SEM[b]**
DM, %/h	5.36	4.90	4.59	3.68	6.02	0.38
NDP, %/h	4.99	4.93	4.42	4.15	5.22	0.43
ADF, %/h	5.30	5.18	4.59	3.10	5.82	0.17
N, %/h[c]	7.21	9.01	4.44	5.49	10.21	0.10

[a]GNB = Great Northern beans to supply 182 g/d CP; CM = canola meal to supply 182 g/d CP; MIX = a mixture of Great Northern beans and sunflower meal to each supply 91 g/d CP; SFM+ = sunflower meal to supply 182 g/d CP; SFM– = sunflower meal to supply 91 g/d CP.

[b]Pooled SEM, n = 2.

[c]Significant a priori contrasts: GNB *vs* SFM+: *P*=0.06; CM *vs* SFM+: *P*=0.02; SFM– *vs* SFM+: *P*=0.02; MIX *vs* GNB: *P*=0.03.

TABLE 4. The effect of varying protein supplements to steers in confinement on in situ estimates of discrete lag time of forage DM, NDF, ADF, and N (soluble pool removed)[a].

	Treatment					
Item	GNB	CM	MIX	SFM+	SFM–	SEM[b]
DM, h	4.2	1.6	3.9	2.6	4.0	2.6
NDF, h	3.0	2.1	3.0	3.0	2.2	2.2
ADF, h	5.2	3.0	4.9	3.9	3.5	3.9
N, h	6.6	8.5	5.2	4.6	8.7	0.9

[a]GNB = Great Northern beans to supply 182 g/d CP; CM = canola meal to supply 182 g/d CP; MIX = a mixture of Great Northern beans and sunflower meal to each supply 91 g/d CP; SFM+ = sunflower meal to supply 182 g/d CP; SFM– = sunflower meal to supply 91 g/d CP.
[b]Pooled SEM, n = 2.

Results and Discussion

Despite apparent differences in measured hay quality across periods (Table 2), period was significant in the model only for the rate of forage N (P=0.04) and ADF (P=0.09) digestion. Treatment had no effect on the rate of digestion of the potentially degradable fractions (readily soluble pool removed) of forage DM, NDF, or ADF (P>0.10; Table 3). Compared with the SFM+ treatment, forage N degraded at a faster rate when steers were on the GNB (P=0.06), CM (P=0.02), or SFM– (P=0.02) treatments. Nitrogen in forage from the MIX treatment degraded slower than that in the GNB treatment (P=0.03). No differences (P>0.10) were detected for forage nutrient lag time (Table 4) or extent of digestion (Table 5). The differences in the rate of forage N digestion could likely be related to the discrete lag time calculated by the model. As shown in Tables 3 and 4, the faster rates of N digestion were associated with numerically higher N lag times. Because no differences existed in the extent of N digestion, the nonlinear model may have calculated a faster rate of digestion for forage N with a longer lag time, simply because nutrients with a longer lag time had to reach the calculated extent of digestion more quickly. It is possible that microbial N contamination of forage fiber created the numerical differences in lag time that led to significant rate of forage N digestion differences.

Because there was not a beneficial response to protein supplementation on in situ forage digestion, as determined by comparing the SFM+ treatment with the SFM– treatment, the medium quality grass hay likely supplied adequate rumen degradable protein. The NRC (12) estimated the average CP requirement of the steers to be 7.5%, and the hay supplied an average of 8.3% CP (across five periods). Therefore, supplementing protein in this experiment was not representative of supplementing protein to typical low quality forage diets.

Feeding raw beans in feedlot diets of young ruminants has been shown to cause diarrhea and depress performance over controls (17, 18; T. L. Stanton, 1997, Dept. Anim. Sci., Colorado State University, Ft. Collins, CO; personal communication). The beans contain lectins and enzyme inhibitors, which can interfere with digestion and absorption of nutrients (3). Researchers have shown that feeding raw beans (*P. vulgaris*) to young pigs can cause a decrease in protein digestibility, reduced pancreatic trypsin, chymotrypsin, and amylase activity, and reduced systemic protein utilization (10, 11). Williams et al. (17) showed that yearling cattle fed raw kidney beans had higher circulating antibodies to bean lectins, indicating absorption of lectins. The forage in situ digestion data in this study indicate that these compounds are not causing adverse effects on forage digestion in the rumen when the beans are supplemented to medium quality hay diets. Indeed, work in eastern Colorado showed raw cull beans (*P. vulgaris*) to be comparable with sunflower meal when fed as a protein supplement to mature cows grazing winter range (13). It is likely that enzyme inhibitors and lectins

TABLE 5. Effect of different protein supplements to steers in confinement on extent of in situ forage degradation of DM, NDF, ADF, and N (soluble pool removed)[a].

	Treatment					
Item	GNB	CM	MIX	SFM+	SFM–	SEM[b]
DM, %	65	60	64	63	60	5
NDF, %	67	64	66	65	64	4
ADF, %	64	61	64	64	60	5
N, %	70	55	66	63	63	6

[a]GNB = Great Northern beans to supply 182 g/d CP; CM = canola meal to supply 182 g/d CP; MIX = a mixture of Great Northern beans and sunflower meal to each supply 91 g/d CP; SFM+ = sunflower meal to supply 182 g/d CP; SFM– = sunflower meal to supply 91 g/d CP.
[b]Pooled SEM, n = 2.

TABLE 6. The rate of in situ degradation of the potentially degradable fractions (soluble pool removed) of DM and N in different protein supplements fed to steers in confinement[a].

	Treatment					
Item	GNB	CM	MIX	SFM+	SFM–	SEM[b]
	(%/h)					
DM	13.7	9.8	13.7	9.5	14.3	6.5
N	9.9	12.1	8.3	15.2	20.1	8.3

[a]GNB = Great Northern beans to supply 182 g/d CP; CM = canola meal to supply 182 g/d CP; MIX = a mixture of Great Northern beans and sunflower meal to each supply 91 g/d CP; SFM+ = sunflower meal to supply 182 g/d CP; SFM– = sunflower meal to supply 91 g/d CP.

[b]Pooled SEM, n = 2.

TABLE 7. In situ estimates of discrete lag time of DM and N in different protein supplements fed to steers in confinement (soluble pool removed)[a].

	Treatment					
Item	GNB	CM	MIX	SFM+	SFM–	SEM[b]
	(h)					
DM	3.7	1.3	3.7	–0.9	1.2	1.1
N	1.0	0.9	–0.7	0.0	1.1	0.7

[a]GNB = Great Northern beans to supply 182 g/d CP; CM = canola meal to supply 182 g/d CP; MIX = a mixture of Great Northern beans and sunflower meal to each supply 91 g/d CP; SFM+ = sunflower meal to supply 182 g/d CP; SFM– = sunflower meal to supply 91 g/d CP.

[b]Pooled SEM, n = 2.

TABLE 8. The extent of in situ digestion of DM and N of different protein supplements fed to steers in confinement (soluble pool removed)[a].

	Treatment					
Item	GNB	CM	MIX	SFM+	SFM–	SEM[b]
	(%)					
DM[c]	105	78	91	74	72	1
N	121	90	110	97	82	11

[a]GNB = Great Northern beans to supply 182 g/d CP; CM = canola meal to supply 182 g/d CP; MIX = a mixture of Great Northern beans and sunflower meal to each supply 91 g/d CP; SFM+ = sunflower meal to supply 182 g/d CP; SFM– = sunflower meal to supply 91 g/d CP.

[b]Pooled SEM, n = 2.

[c]Significant a priori contrasts: GNB *vs* SFM+: *P*=0.02; CM *vs* SFM+: *P*=0.13; MIX *vs* GNB: *P*=0.04.

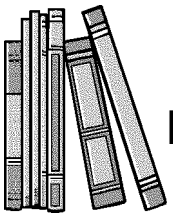
exert their negative effects in the small intestine of ruminants, and the activity of these compounds in the intestine may be affected by diet type.

Table 6 shows the rate of in situ degradation of the potentially degradable fractions (readily soluble pool removed) of DM and N in the protein supplements incubated. There were no differences in the rate of DM or N degradation between the treatments (P>0.80). The GNB and MIX treatment supplements had numerically higher DM discrete lag times than other supplements, yet no differences were detected between treatments (P>0.40; Table 7). The extent of in situ digestion of DM and N was variable among treatments (Table 8). Canola meal had a greater extent of DM degradation than did sunflower meal from the SFM+ treatment (78 *vs* 74% for CM and SFM+, respectively; P=0.13). The calculated 78% extent of DM digestion for CM is slightly lower than that 76-h (83%) extent determined by Boila and Ingalls (2). The GNB supplement was estimated by the model to be over 100% degradable, as it appears that the ground beans were able to pass out of the rumen bag. The 0-h bags containing beans lost 37% because of washing and handling, compared with 33% for CM and 23% for SFM. Grinding the beans through the 2-mm screen created a fine powder that could possibly escape through the 50-mm pores of the bag. Therefore, differences noticed in extent of DM degradation in the GNB and MIX treatments are difficult to interpret. Because high variability, no differences were detected in the extent of supplement N degradation (P>0.50; Table 7).

Forage intake, as determined during the 3-d intake measurement during each period, averaged 1.5% BW (data not shown). No differences were detected among treatments (P>0.56).

Great Northern beans, canola meal, or a mixture of Great Northern beans and sunflower meal had

similar responses on in situ forage digestion when supplemented to a medium quality grass hay diet. The extent of in situ bean degradation was confounded by apparent escape of the beans from the Dacron bag. Canola meal insoluble DM was more degradable than that of sunflower meal, yet the rate of DM degradation did not differ. More research is necessary to determine the effects of these supplements on digestibility of low quality forage diets and the impact of raw cull beans on total tract digestibility.



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