RUMEN ESCAPE AND LOWER GASTRIC INTESTINAL TRACT DIGESTION OF ESSENTIAL AMINO ACIDS FROM CANOLA MEAL

J.R. Ingalls, S.A. Moshtaghi-Nia, R. Boila, E. Kendall

Department of Animal Science, University of Manitoba
Winnipeg, Manitoba, Canada R3T 2N2

INTRODUCTION

Much of the dietary protein that enters the rumen is degraded to peptides and amino acids which are ultimately deaminated. Measurement of both the rumen degradability of protein in a feedstuff and the post-ruminal digestibility of rumen-escape components of dietary origin are required. The incubation of feedstuffs in situ for various time intervals in the rumen allows estimation of the degradability of feedstuffs' components (Nocek 1988) and the size of the non-degradable or rumen bypass fraction of that component. The intestinal availability of nutrients that escape rumen fermentation has been estimated using a mobile nylon bag technique (de Boer et al. 1987b). Although rumen degradability of CM has been evaluated little work has been completed to compare the rumen degradability and post-ruminal utilization of CM produced from different processing plants.

Heat treatment (baking and roasting) has been used to decrease the rumen degradability of rapidly degraded protein sources such as CM and soybean meal. The increase in protein escape through heating may be a result of protein denaturation and reduction in solubility and degradation rate which favors more rumen escape of intact undegraded proteins to the lower gastrointestinal (GI) tract. Dry heat treatment is time consuming and, if used commercially, would require a substantial equipment investment per ton of capacity. Moist heat is applied to CM during the extraction process at the canola crushing plant.

The objective of this study was to compare the rumen degradability and post-ruminal digestion of rumen-escape DM, N and metabolically essential amino acids of samples of CM from five different processing plants, and a sample of soybean meal (SBM) and the effect of moist heat on N available in the lower gastrointestinal tract.

Trial 1

MATERIALS AND METHODS

Experimental Protocol

A sample of CM was obtained from each of five different processors in Western Canada and designated as samples 1 to 5. A sample of SBM was obtained from a processor in southern Manitoba and designated as sample 6. Proprietary information concerning manufacturing procedures were not provided by the different processors.

Five separate incubations were conducted. Each incubation consisted of two parts. The first part entailed the incubation of nylon bags in situ in the rumen of two Holstein steers each fitted with a rumen cannula. Nylon bags were incubated in situ: Incubation 1, 16 h; Incubation 2, 12 h; Incubation 3, 8 h; Incubation 4, 4 h; and Incubation 5, 30 h. The second part of each incubation entailed ruminal incubation of samples within nylon bags and these bags were digested in vitro in an acid-pepsin solution and then exposed to intestinal digestion as a mobile nylon bag in three Holstein steers, each fitted with a T-shaped cannula. The crude protein and acid detergent fibre (ADF) levels of the diets were 18.5% and 14.0%, respectively (DM basis).

Small nylon bags, 3.5 x 5.5 cm, were prepared by heat-sealing after filling with 0.5 g of sample as received from the processor. The small nylon bags were held in panty hose (porosity not less than 100 μM) weighted down with glass marbles during the rumen fermentation period. After removal from the rumen, 16 nylon bags for each of the six samples and blanks were washed under cold tap water for 1 to 2 min until the rinse water was colorless, and then dried in a forced air oven at 60°C for 48 h in preparation for analyses.

Also 16 bags from each of the six samples and blanks not prepared for analyses after ruminal incubations were incubated in a pepsin-HCl solution for 3 h at 39°C (Sauer et al. 1983; Kirkpatrick and Kennelly 1985). Nylon bags were inserted randomly into each of the three duodenally-cannulated

steers at the rate of 2 bags h^{-1} and collected from the feces.

The equation of Orskov and McDonald (1979), $p = a + b (1 - e^{-ct})$, where p was the amount degraded at time (t), was used to estimate the constants a, b and c required to calculate the effective degradabilities of DM and N.

Four nylon bags containing sample plus blanks from each of the ruminal and mobile bag incubations were analyzed for N, DM and diaminopimelic acid (DAPA). From each of the rumen incubations, and mobile bag fecal residue, two nylon bags from a samples were used for an analysis of amino acids other than methionine and cystine, while two were used for analysis of methionine and cystine.

RESULTS AND DISCUSSION

The contribution of bacterial N, as a percentage of the total N in rumen residues averaged 3.7, 5.2, 4.2, 1.8 and 2.0% for 4, 8, 12, 16 and 30 h, respectively, while that for mobile bag residues averaged 2.1, 3.5, 3.3, 3.0 and 1.6% for 0, 4, 8, 12 and 16 h, respectively.

The rumen escape of DM and N differed among CM samples, and between CM samples and the SBM sample. Two distinct features of the data were: (1) the lower rumen escape N from CM1 vs other CM samples at all rumen fermentation times except 30 h; and (2) the high escape of CM4 in relation to other CM samples and SBM at 30 h. There was a high solubility of DM and N for CM1; although the loss of DM measured at t=0 may include both the soluble fraction and a mechanical loss of feed particles (Nocek 1988), for CM1, the lower escape of DM at 4 h and N at 4, 8 and 12 h was indicative of a higher degradability for CM1 than for other CM samples. The higher rumen escape of DM and N for CM4 at 30 h was evidence that this sample of CM was the least degradable of all samples evaluated.

The means for rumen escape of DM and N in CM samples were similar, particularly at 4 and 8 h, to those reported by Ha and Kennelly (1984) but higher than those reported by de Boer et al. (1987a). The rumen escape values for CM at 12 and 16 h are higher than in Trial II and higher than most studies.

The pattern of a higher fecal DM residue for CM samples than SBM was established at t=0 and was maintained at each fermentation time. The trend for N in fecal residues among fermentation times was quite similar to that noted with DM. The mean fecal residue for DM among fermentation times ranged from 24.5% to 32.1% for CM samples and 7.4 to 14.6% for SBM, while that for N ranged from 10.2 to 14.8% for CM samples and 2.3 to 6.2% for SBM. It was estimated that 9% and 2% of the N in CM and SBM, respectively, were associated with the hull. The differential in percentages of hulls between CM and SBM may explain the higher recovery of DM and N in feces with CM samples. Apparent digestibility of CM hulls is low.

At t=0 the mobile bag digestibility of N ranged from 82.9 to 90.7% (mean 87.1, SE=1.32) for the five CM samples and was 93.8% for SBM. Since these samples were not exposed to rumen fermentation, they were compared to the digestibilities of CM and SBM obtained with pigs using the mobile nylon bag technique (Cherian et al. 1988). Cherian et al. (1988) reported a N digestibility of 77 to 78% for CM and 90 to 94% for SBM. While the data for SBM were similar for pigs and cattle, for CM the digestibility of N in CM was apparently higher with steers.

Within each fermentation time the rumen escape of the six amino acids, lysine, threonine, valine, isoleucine, leucine and phenylalanine was relatively uniform for each sample of CM. The fact that CM1, with its tendency for a lower escape of these amino acids, differed from other CM samples, and agreed with the rumen escape data for DM and N. The rate of microbial degradation for these amino acids up to 16 h of fermentation was similar for each sample of CM. Only at 16 h was there an indication that the rumen escape of these six amino acids in CM samples was higher than that in SBM.

For CM samples the escape of histidine from microbial degradation at 12 h was about one-half that of other amino acids in CM samples and one half that of histidine in SBM; however, at 16 h there was no difference for histidine between other amino acids, CM samples or SBM. The recovery of histidine in the mobile bag residues for CM was about one-half that of the other amino acids from CM.

The recovery of amino acids in mobile bag residues (fecal residue) was different for each of histidine, methionine and cystine than the other amino acids. For lysine, threonine, valine, isoleucine, leucine and phenylalanine the recovery in mobile bag residues from CM samples was 2 -

3 times higher than that from SBM. The rumen escape of methionine in SBM, 62.7% at 8 h and greater than 100% at 4, 12 and 16 h, was high. Contamination of the SBM residue with bacterial N, which ranged from 3 to 5% of the N in residues for 4, 8 and 12 h cannot account for a recovery of greater than 100% methionine. If Varvikko et al. (1983) were correct that analytical error contributed to a similarly high recovery of methionine in formaldehyde-treated SBM, then analytical error approached 100%. A methionine content of 0.68 g (16 g N)$^{-1}$ for SBM in this report was apparently low compared to a value of approximately 1.4 g (16 g N)$^{-1}$ (DM basis) reported by Smith and Circle (1978) and Ganev et al. (1979) but agreed with a value of approximately 0.8 g (16 g N)$^{-1}$ reported by MacGregor et al. (1978) and Varvikko et al. (1983). The data for SBM were indicative of a high rumen escape value for methionine. A recovery of more than 100% of the original content of methionine in rumen escape residues for SBM must be examined more fully.

While the rumen escape of DM, N and amino acids from a feedstuff decreased with an increase of fermentation time, the recovery of these nutrients in mobile bag residues remained relatively constant among fermentation times, and was higher with CM samples than SBM. Consequently the major determinant of the amount of nutrient in a feedstuff that was digested post-ruminally was the level of rumen escape for that nutrient.

The post-ruminal digestion of amino acids differed between CM1 and other CM samples and between CM samples and SBM. For CM1 compared to other CM samples after 16 h of incubation there was 49% less histidine and a range of 29 to 40% less of other amino acids digested post-ruminally. A comparison of the mean of CM samples other than CM1 to the value obtained for SBM revealed that for 12 h samples there was 10 to 36% less amino acid digested with CM samples in the lower GI tract but at 16 h there was 25% more amino acid digested with a high of 53% more phenylalanine digested, but with no major difference between samples for methionine. The post-ruminal contribution of amino acids from CM was always lower than that of SBM at 12 h, while at 16 h, exclusive of methionine, that contribution was higher than SBM for all CM samples except CM1. These data for amino acids digested were a reflection of the rumen escape of N and individual amino acids at 12 and 16 h, and the effective degradable n values for these samples at a rumen turnover rate of 0.08 h^{-1}.

CONCLUSIONS

The rumen degradability and post-ruminal digestion of DM, N and metabolically essential amino acids were compared for CM samples from five different processing plants and one sample of SBM. The rumen escape of nutrient in a sample decreased as fermentation time increased, while the level of residual nutrient recovered in mobile bags was relatively uniform, particularly at 12 and 16 h of rumen fermentation. Therefore the extent of digestion in the rumen had a greater influence than post-ruminal digestion on the post-ruminal provision of digestible nutrients in CM.

The levels of DM, N and metabolically essential amino acids in mobile bag residues were higher with CM than with SBM. A higher percentage of hull and the N content of those hulls in CM appeared to be the reason for the limited post-ruminal digestion of rumen escape nutrients in CM compared to SBM.

A major difference among CM samples was the low rumen escape of nutrients in CM1 at all fermentation times and the high rumen escape of CM4 after 30 h of rumen fermentation. The CM1 sample was a poor source of N and metabolically essential amino acids post-ruminally, while it was estimated that CM4 would provide a level of nitrogenous components greater than that of other CM samples or SBM when the rumen turnover approached 0.03 h^{-1} or less.

Trial 2

MATERIAL AND METHODS

Three Angus steers weighing 675 kg, fitted with large diameter rumen cannula and two Holstein steers weighing 350 kg, fitted with T type duodenal cannula were used for rumen degradation and lower GI tract studies, respectively. Cannulated steers during the study received dairy type rations used for high producing dairy cows. The mean daily DM intake was 8.6 kg for rumen cannulated steers and 5.9 kg for duodenal cannulated steers. Feed was provided to both groups of steers twice a day at 0800 and 1600 h.

Commercially available CM was spread in a tray to a depth of 1 cm and autoclaved for 15, 30, 45, 60 and 90 minutes. After heating, CM was allowed to cool to ambient temperature and then stored in plastic bags. One gram samples of each treatment were placed in small heat sealed nylon bags (see Trial 1) and incubated in the rumen of three steers for 10 and 16 h. Triplicate bags were incubated in the rumen of each of the three steers. All bags were removed from the rumen together and immediately washed in a washing machine for 15 min. Duplicate samples were incubated in each steer for 10 and 16 h in the rumen, incubated in pepsin-HCl for three h to simulate abomasal digestion and then inserted into the duodenum of the two steers through the duodenal cannula at the rate of two bags/h and collected in the feces. Bags recovered from the feces were treated similarly to the bags removed from the rumen. The travel time for each bag lasted approximately 12 h from duodenum to feces.

RESULTS AND DISCUSSION

Treatment had no significant ($P>0.05$) effect on total N while N solubility was reduced ($P<0.01$) from 32% for control meal to 7 to 10% at all treatment times (Table 1). The percentage N recovered as ADIN and pepsin insoluble N increased ($P<0.05$) with heating time. Heating of CM for 15 and 30 min resulted in a small increase in ADIN while 45 and 90 min resulted in a 267% and 683% increase in ADIN, respectively. With increased heating time the NDIN content progressively increased ($P<0.05$) to 740% with 90 min heating. Heating of CM had a similar effect on the ADF and NDF content as it did on ADIN and NDIN content. The percentage increase over the control for ADF and NDF was 130% and 124% at 90 min heating. At 16 h incubation time in the rumen, moist heat treatment for 15 and 30 min reduced DM and N disappearance (Table 2). Treatment above 30 min had very little further effect on DM and N disappearance in the rumen. All heat treatments increased ($P<0.05$) lower GI tract digestion of N by 249 to 299% (Table 2) with no decrease in digestion with the longer heat treatments. Heating for 45 min and longer reduced ($P<0.05$) total tract digestion of N.

CONCLUSIONS

Moist heat treatment of a commercial canola meal resulted in increased ADIN, decreased rumen degradation, decreased rumen solubility with large increases in lower gut digestion of N. Moist heat treatment would seem to offer potential for increasing the amount of canola meal digested in the lower GI tract of ruminants.

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REFERENCES

CHERIAN, G., SAUER, W.C. and THACKER, P.A. 1988. Effect of predigestion factors on the apparent digestibility of protein for swine determined by the mobile nylon bag technique. J. Anim. Sci. 66:1963-1968.

DE BOER, G., MURPHY, J.J. and KENNELLY, J.J. 1987a. A modified method for determination of in situ rumen degradation of feedstuffs. Can. J. Anim. Sci. 67: 93-102.

DE BOER, G., MURPHY, J.J. and KENNELLY, J.J. 1987b. Mobile nylon bag for estimating intestinal availability of rumen undegradable protein. J. Dairy Sci. 70:977-982.

GANEV, G., ORSKOV, E.R. and SMART, R. 1979. The effect of roughage or concentrate feeding and rumen retention time on total degradation of protein in the rumen. J. Agric. Sci., Camb.93: 651-656.

GOERING, H.K. and VAN SOEST, P.J. 1970. Forage fiber analysis. Agric. Handbook No. 379, USDA, Washington, DC.

HA, J.K. and KENNELLY, J.J. 1984. In situ dry matter and protein degradation of various protein sources in dairy cattle. Can. J. Anim. Sci. 64: 443-452.

HECKER, J.F. 1974. Experimental surgery on small ruminants. Butterworth and Co. Ltd., London.

NOCEK, J.E. 1988. In situ and other methods to estimate ruminal protein and energy digestibility: A review. J. Dairy Sci. 71:2051-2069.

ORSKOV, E.R. and MCDONALD, I. 1979. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. (Camb.) 92: 499-503.

Table 1. The effect of moist heat treatment of canola meal on various fiber fractions and nitrogen associated with those fractions.

	Heat treatment (min)						
Item	0	15	30	45	60	90	SEM
Total N (%)	6.44	6.49	6.43	6.48	6.55	6.58	0.04
ADF (%)	15.8d	14.2d	15.0d	23.3c	28.3b	36.4a	0.55
NDF (%)	24.9f	35.3e	40.1d	48.2c	52.1b	55.7a	0.76
N composition, % of total N							
ADIN	5.35d	6.55d	6.99d	19.53c	26.52b	41.09a	0.66
PIN	13.3e	15.2de	16.2cd	18.3bc	20.3b	23.9a	0.68
NDIN	8.4f	26.3e	35.3d	45.5c	58.4b	70.2a	1.87
Sol. N	32.4a	7.0c	7.6bc	8.1bc	9.3bc	9.7b	0.50

Table 2. The effect of moist heat treatment of canola meal on rumen nitrogen degradability, lower GI tract digestion and fecal residue and total tract digestion after 16 hr rumen incubation as a percent of original nitrogen

	Heat treatment (min)					
Item	0	15	30	45	60	90
Rumen	74.4a	30.1b	21.3c	18.9cd	17.3d	17.4d
Lower GI tract	16.2b	56.5a	64.7a	64.2a	62.5a	64.5a
Fecal Residue	9.3	13.3	13.9	16.8	20.1	18.0
Total tract	90.5a	88.2ab	85.9abc	83.2bc	79.8c	82.4bc