Protected (bypass) Protein and Feed Value of Hazelnut Kernel Oil Meal[a]

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ABSTRACT : *In situ* and *in vivo* digestion trials were conducted to determine the degradation of dry matter (DM), crude protein (CP) and effective protein degradability (EPD), and digestibility of nutrients of Hazelnut kernel oil meal (HKOM), and effects of HKOM on nitrogen (N) balance. In the *in situ* study, nylon bag were suspended in the rumen of 3 Karayaka rams to estimate protected protein. Protein sources were analyzed for pepsin soluble protein (PSP) using a Pepsin Digestion Method. In the digestion trials, 4 Karayaka rams (36 mo.) were used in a 4×4 Latin square to evaluate the digestibility of nutrients and N retention to measure effects of diets containing HKOM, soybean meal (SBM) corn gluten meal (CGM) and urea (U). The degradability of DM and CP, and PSP content of HKOM were lower ($p>0.05$) than that of SBM, but higher ($p<0.01$) than that of CGM. EPD of HKOM was higher ($p<0.01$) than that of SBM or CGM. The apparent digestion coefficients of organic matter and CP for HKOM were lower than for SBM, but higher than for CGM. N retention of HKOM was higher than that of SBM and lower than that of CGM ($p>0.05$). In conclusion, these data may indicate that the HKOM is a high digestible feed source with a value between SBM and CGM. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 3 : 317-322*)

Key Words : Hazelnut Kernel Oil Meal, Protein Sources, Protein Degradation, Bypass Protein

INTRODUCTION

The most important source of N for the rumen microbes is dietary protein including non-protein N (NPN). When high quality protein in soybean meal (SBM) or hazelnut kernel oil meal (HKOM) is fed to ruminants it is subjected to microbial fermentation during which most N sources are degraded to peptides, amino acids and finally to ammonia (MacDonald et al., 1987). In such cases the advantages of protein quality in terms of the balance of absorbable essential amino acids and protein is lost (Mir et al., 1984; Ørskov, 1992).

Only a portion of the protein requirement of young growing ruminants and lactating dairy cows can be met by microbial protein synthesis (Loerch et al., 1983a, b). To maximize performance in these stages of production, dietary protein must escape rumen degradation to be available for absorption from the small intestine (Owens and Bergen, 1983; Ensminger et al., 1990).

Protein-rich feedstuffs are a major expense in animal nutrition as it is the primary purchased feed in many cases. SBM has been the most widely used protein source and is the standard by which other protein sources are judged. During the past 20 years, the price SBM has ranged between 2 and 2.5 times the price of corn, suggesting that protein is much more expensive than energy. Therefore, it is important to minimize the use of protein-rich feedstuffs in ruminant rations.

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HKOM is high in crude protein (CP), relatively low in crude fiber (CF), readily digestible (the extents of digestion of CP and CF were 78.96 and 75.78, respectively) and has a high palatability (Akyildiz, 1970, 1986; Ocak et al., 1994). However, the rumen degradability of dry matter (DM) and CP, and its use in diets for growing ruminants and dairy cows are not studied. The objectives of this study were to determine the rumen degradation characteristics of DM and CP, its effective protein degradability (EPD), digestibility of its nutrients as well as effects of HKOM on N balance in lambs.

MATERIALS AND METHODS

In situ and pepsin digestion

Three protein feed sources were studied; SBM, CGM and HKOM. The degradability of the 3 protein sources was measured separately. Three Karayaka rams with average live weight 54 kg, fitted with rumen cannulae (Preston, 1985) were used.

Rumen cannulated rams were fed grass hay (GH) and a concentrate designed to meet the DM requirements along the experiment. Nylon bags (8×14.5 cm) having a 40 μm diameter pore size were used throughout the study.

The *in situ* degradability of each protein source was measured using the nylon bag technique of Ørskov and McDonald (1979) and Van Straalen et al. (1993). Duplicate bags containing about 5 g DM were introduced into the rumen and incubated for 0, 4, 8, 12, 24 and 48 h. After incubation, bags were rinsed in running tap water to remove adhering digesta and then washed twice in a pool of water (30℃) for 5 min to remove rumen fluid. They were dried at 65℃

for 48 h in a forced-draught oven, allowed to air-equilibrate and weighed.

The degradability data obtained from each ram for DM and CP were interpolated with the non-linear model:

$$P = a + b\ (1 - e^{(-ct)})$$

Where: 'P' is degradability at time (t); 'a' is the rapidly soluble fraction (i.e., zero time intercept); 'b' is the potentially degradable fraction; 'c' is the rate constant of degradation of 'b' and 't' is the time of rumen incubation. Effective degradability (ED) was calculated with the estimated rates of outflow from the rumen (k), (k= 0.04 and 0.06/h) using the relationship:

$$ED\ (\%) = a + (bc/c+k)\ (1-e^{-(c+k)t})$$

In the pepsin digestion method, triplicate samples of 0.5 g of SBM, CGM and HKOM plus 50 ml of 0.1% pepsin in 0.01 N HCl were placed in 100 ml centrifuge tubes and incubated in a water bath at 40℃ for 24 h. Digestion was stopped by the addition of 10 ml of 10% trichloroacetic acid (TCA). The mixture was squeezed through Whatman 541 paper and washed with 3% TCA (Mir et al., 1984; Akyildiz, 1984) and the N content was estimated by Kjeldahl procedure (AOAC, 1984).

Digestion and N balance

Four Turkish native Karayaka rams, aging 36 months were used in the digestion and N balance experiments. In this trial, SBM, CGM, HKOM and grass hay were used as feedstuffs. The trial was a 4× 4 Latin square design and consisted of a 7 day transition, a 8 day preliminary, and a 10 day measurement period. Protein supplement+HG mixtures (1/1), prepared to meet 80% of the DM requirements were given twice a day (as DM basis). The proportion of the protein supplement in the rations was adjusted to meet about twice the CP requirements (Deniz and Tuncer, 1995b). Quantitative collection of faeces and urine during the measurement period of the trial was carried out according to Matras et al. (1991) and Deniz and Tuncer (1995b).

Chemical analysis

Proximate analysis of the feeds and faeces, and N concentration in urine were performed according to AOAC (1984). Protein sources were analyzed in triplicate to determine the amino acid profile. Following acid hydrolysis (6 N HCl at 110℃ for 12 h) of meals, amino acids were separated and quantified using a model 119B amino acid analyzer (Beckman Instruments Inc., Palo Alto., Calif.) (Mir et al., 1984).

Statistical analysis

Data obtained from the *in situ* and pepsin digestion trials were analyzed as a randomized plot design. Analysis of variance was performed according to an ANOVA model, using the ONEWAY procedure of the *MSTAT-84* package. Data of digestion and N balance trials were analyzed in a Latin Square design. Differences between means were tested with Duncan's Multiple Comparison Test as detailed by Düzgünes et al. (1987).

RESULTS

***In situ* and pepsin digestion**

Pepsin Digestion of Protein (PDP) content of HKOM, 77.86 (SE=0.13), were lower ($p>0.05$) than that of SBM, 80.93 (SE=0.05), but higher ($p<0.01$) than that of CGM, 38.67 (SE=0.09).

The EPD values of HKOM, SBM and CGM were found as 56.57, 59.43 and 31.20 (SE=0.34) for the rate of passage 0.06 and 62.73, 65.40 and 35.40 (SE= 0.49) for the rate of passage 0.04, respectively (table 1). Significant differences were determined among the protein sources in terms of 0.h N loss due to microbial activity and degradation rate of N ($p<0.01$) and these differences were supposed to arise from CGM.

Table 1. Effective protein degradability characteristics of protein sources, %

Protein source	a	b	c	0.04[1]	0.06[1]
CGM	12.79[a]	38.14[a]	0.073[a]	35.40[a]	31.20[a]
HKOM	15.69[b]	65.34[b]	0.133[b]	62.73[b]	56.57[b]
SBM	16.24[b]	66.44[b]	0.134[b]	65.40[c]	59.43[c]
SEM[2]	0.26	0.76	0.01	0.49	0.34
F	50.35**	444.67**	24.93**	1152.33**	2116.76**
CV	3.03	2.32	0.11	1.55	1.19

[1] k values. [2] Standard error of the mean.

**($p<0.01$); [a,b,c] Means in the same column with different superscripts ($p<0.05$).

Table 2. Amino acids contents of protein sources before and after 12 h *in situ* incubation (g/100 g CP)

AA	SBM		HKOM		CGM	
	before	after	before	after	before	after
Asparagine	8.89	9.00	10.33	7.31	11.75	6.37
Threonine	3.46	3.32	3.22	2.73	4.43	3.42
Serine	3.85	3.81	4.43	3.02	5.07	5.19
Glutamine	17.14	13.78	23.52	11.43	17.61	23.36
Proline	1.26	0.87	0.98	0.71	1.16	2.33
Glycine	4.21	2.58	3.12	2.22	3.44	1.80
Tot. NEAA	38.90	33.26	45.60	27.42	43.47	42.47
Alanine	3.07	1.61	2.34	1.39	2.19	4.44
Valine	3.15	2.82	3.17	2.30	3.86	3.18
Methionine	0.77	0.91	0.91	0.65	1.29	1.79
Isoleucine	4.77	4.46	4.03	3.36	6.17	4.46
Leucine	6.56	6.73	7.45	5.26	9.07	18.22
Tyrosine	3.51	3.31	3.05	2.30	4.55	5.15
Phenylalanine	6.01	4.92	5.24	3.67	6.62	7.16
Histidine	3.25	2.30	2.68	2.00	3.02	1.96
Lysine	6.09	4.48	2.41	3.38	5.73	1.57
Arginine	4.03	4.70	12.23	4.48	6.47	2.83
Tot. EAA	41.22	36.32	43.52	28.79	48.96	50.75
Tot. AA	80.12	69.60	89.12	56.21	92.43	93.22
NH_3	1.11	1.01	1.25	0.92	1.28	1.68

Amino acid contents of protein sources (amino acid contents in residues from nylon bags) are in table 2. Non-essential AA (NEAA), essential AA (EAA) and total AA (TAA) values of HKOM (45.60, 43.52 and 89.12 g/100 g CP) were higher than those of SBM (38.90, 41.22 and 80.12 g/100 g CP) and were lower than those of CGM (48.96 and 92.43 g/100 g CP) except NEAA (43.47 g/100 g CP). While aspartic acid, methionine, leucine and arginine contents of SBM; lysine content of HKOM and serine, glutamic acid, proline, alanine, methionine, leucine, tyrosine and phenylalanine contents of CGM were increased, the other AAs of all the protein sources were decreased compared to their original forms. Particularly, branched chain AAs (BrAA) were decreased except leucine. SBM and CGM were similar in terms of variation in methionine and lysine. The post-incubation change in terms of total NEAA content were negative for each of 3 protein sources (-39.87, -14.24 and -2.30 for HKOM, SBM and CGM, respectively). But there was a little change compared to its original form. While there was a reduction in terms of total EAAs for HKOM (-33.85%) and SBM (-11.89%) compared to pre-incubation feed, there was an increase for CGM (3.66%).

Digestion and N-balance trial

Results of digestion trial and N-balance trial are shown in table 3 and table 4. DM, OM, CP and EE digestibilities of HKOM (83.94, 86.23, 87.43 and 82.63%) were higher than CGM (82.55, 83.05, 86.99

Table 3. Results of digestion trial

Feeds	DM	OM	CP	EE	CF	NFE	Ash
Nutrients, %							
HG	87.48	(90.36)	(9.99)	(2.19)	(40.31)	(7.87)	(9.64)
SBM	89.42	(92.67)	(43.32)	(5.95)	(7.37)	(36.04)	(7.31)
HKOM	88.93	(92.52)	(45.71)	(4.23)	(12.35)	(30.24)	(7.48)
CGM	90.59	(98.65)	(65.49)	(0.99)	(1.25)	(30.93)	(1.32)
Extents of digestion, %							
HG	55.92	56.79	47.24	45.49	57.85	58.85	
SBM	90.51	91.27	89.39	91.83	77.77	96.33	
HKOM	83.94	86.23	87.43	82.63	58.32	97.40	
CGM	82.55	83.05	86.99	69.75	83.23	75.12	
Digestible nutrients, %							
HG	48.92	(51.32)	(4.72)	(1.00)	(23.32)	(22.29)	
SBM	80.94	(84.58)	(38.72)	(5.46)	(5.73)	(34.72)	
HKOM	74.65	(79.78)	(39.96)	(0.82)	(7.20)	(29.45)	
CGM	74.78	(81.93)	(56.97)	(0.69)	(1.04)	(23.23)	

*The values in parenthesis are in DM basis.

Table 4. Results of nitrogen balance trial

Items	HG	SBM	HKOM	CGM	F	CV
N intake, g/d	16.63 ± 1.50^{C}	36.59 ± 2.17^{AB}	39.90 ± 0.91^{A}	33.59 ± 0.77^{B}	85.73**	7.06
N in feces, g/d	8.83 ± 1.02^{Bb}	3.81 ± 0.38^{Aa}	5.31 ± 0.22^{Aba}	4.37 ± 0.37^{Aa}	11.01**	24.42
N in urine, g/d	6.80 ± 0.32^{B}	28.27 ± 2.45^{A}	28.27 ± 1.32^{A}	21.96 ± 0.97^{A}	59.05**	12.36
N retention, g/d	1.00 ± 0.05^{B}	4.51 ± 0.61^{A}	6.32 ± 0.59^{A}	7.26 ± 0.03^{A}	19.39**	26.39

* ($p<0.05$); ** ($p<0.01$).

^{a,b} Means in the same row with different superscripts significantly differ ($p<0.05$).

^{A,B,C} Means in the same row with different superscripts significantly differ ($p<0.01$).

and 69.75%) and lower than SBM (90.51, 91.27, 89.39 and 91.83%). However, CF digestibility of HKOM was lower than that of CGM and SBM (58.32% vs. 83.23 and 77.77%, respectively) and NFE digestibility of HKOM was higher than that of CGM and SBM (97.40% vs. 75.12 and 96.33%, respectively). Digestible OM content of HKOM (79.78%) was lower than that of SBM and CGM (84.58 and 81.93%, respectively). Digestible CP content of HKOM (39.96%) was higher than that of SBM (38.72%) and lower than that of CGM (56.97%).

As shown in table 4, N retention (g/day) or retention rate (% of intake and digested N) was not different among protein sources ($p>0.05$). However, HKOM (6.32 ± 0.59 g/d, 15.93 ± 1.73 and 18.27 ± 2.12%) had between SBM (4.51 ± 0.61 g/d, 12.38 ± 1.68 and 15.10 ± 2.87%) and CGM (7.26 ± 0.03 g/d, 21.51 ± 2.73 and 24.81 ± 3.37%).

DISCUSSION

DM and CP degradabilities and EPD values of the SBM and CGM were found to be numerically higher than in previous studies (Ørskov and McDonald, 1979; Mir et al., 1984). Deniz and Tuncer (1995a) reported that DM and CP degradabilities and EPD values were SBM of 73.56, 70.80 and 67.07%, respectively (after 12h incubation). While Mir et al. (1984), Çetinkaya et al. (1990) and Madsen and Hvelplund (1994) found EPD values of SBM as 60.9, 58.4 and 63.0% respectively. Cleale et al. (1987a) found by-pass value of SBM 13.1%. Sehgal and Marker (1994) noted the *in vitro*, *in sacco* and *in vivo* protein degradabilities for CGM of 24.6, 60.9 and 31.3%, respectively. In this study DM and CP degradabilities and EPD values of SBM were: 85.59, 68.37 (after 12 h incubation) and 62.27, respectively.

Conflicting results might be due to *in vitro* bag pore size, ratio of sample size to bag surface area, sample particle size, animal's diet, incubation time, chemicals used (Cummins et al., 1983; Stern and Satter, 1984; Madsen and Hvelplund, 1994). Ørskov (1992) reported variations in terms of DM degradability between animals (6.2%), days (4.9%) and dacron bags (3.3%) in the same study.

There are some contradictions among various studies in terms of AA disappearance or variation rate in post-incubation period. Mir et al. (1984) reported that histidine, arginine, lysine and leucine contents of SBM decreased after 12 h incubation. Weakley et al. (1984) reported that there were significant changes in the content of 14 different AAs compared with their original contents. Ørskov (1988) reported an increase in aspartic acid, threonine, serine, proline, alanine, valine, methionine, cystine, isoleucine, leucine and phenylalanine contents of SBM after a 9 h incubation period. Goedeken et al. (1990) found an increase in isoleucine, leucine, lysine, methionine, phenylalanine, tyrosine, valine and cystine contents and a decrease in arginine, histidine and tryptophan contents after a 12 h incubation period. Erasmus et al. (1994) reported that degradability of BrAAs in the rumen was low. The same authors stated a decrease in phenylalanine and lysine contents in the rumen undegradable protein for most protein sources. Cozzi et al. (1995) and Weakley et al. (1984) found a difference in AA degradabilities dependent upon protein sources and animal's diet, and also reported that the arginine, histidine and lysine contents of SBM and CGM increased after a 8-16 h incubation period. The results concerning the degradability of AAs in the present study agree with these studies mentioned above.

The findings mentioned above indicate that HKOM is equal to CGM and SBM in terms of nutrient contents, digestibilities and digestible crude nutrients. Some of the previous studies supported this suggestion (Özen and Erener, 1992; Ocak et al., 1994).

In N balance trial N retention rate (% of intake and digested N) was not affected by protein sources. Merchen et al. (1987) mentioned that urea, SBM and CGM additions to the compounds with 10.5 or 12% CP at maintenance energy level did not affect N utilization. However, the higher values obtained with CGM can be due to higher by-pass protein content and also higher digestibility of by-pass protein in the small intestine (Ensminger et al., 1990; Deniz and Tuncer, 1995a). Matras et al. (1990 and 1991) compared 3 diets composed of urea, urea+blood meal+CGM or

blood meal+CGM and consequently concluded that blood meal+CGM diet was higher than the other diets in terms of N consumption and the N retention rate (% of digested N). The same authors also reported an increase (20%) in terms of N retention when 64% of the N supplementation was met from BM+CGM. The difference between HG and protein supplements can be explained by decreased N amount and N quality in case of HG consumption (Aderibigbe and Church, 1983).

In conclusion, these data indicate that the HKOM is a highly digestible feed source between SBM and CGM and very comparable to SBM with a high ruminal degradability.

REFERENCES

Aderibigbe, A. O. and D. C. Church. 1983. Feather and hair meals for ruminants: II. Comparative evaluation of feather and hair meals as protein supplements. J. Anim. Sci. 57:473-483.

Akkiliç, M., A. Ergün and H. Erdin. 1982. Utilizing hazelnut kernel oil meal in broiler diets. J. Ank. Uni. Vet. Fac. 29:369.

Akyildiz, A. R. 1970. A digestion trial with an hazelnut oil extraction meal. Ank. Uni. Agr. Fac. 2:391-394.

Akyildiz, A. R. 1984. Feed Analysis Laboratory Guide. Ank. Uni. Agr. Fac. Pub. pp. 893, Ankara.

Akyildiz, A. R. 1986. Feeds and Feed Technology. Ank. Uni. Agr. Fac. Pub. pp. 974, Ankara.

AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists Washington, DC.

Cleale IV., R. M., B. R. Britton, T. J. Klopfenstein, M. L. Bauer, D. L. Harmon and L. D. Satterlee. 1987a. Induced non-enzymatic browning of soybean meal. II. Ruminal escape and net portal absorption of soybean meal protein with xylose. J. Anim. Sci. 65:1319-1326.

Cozzi, G., I. Andrighetto, P. Berzaghi and C. E. Polan. 1995. *In situ* ruminal disappearance of essential amino acids in protein feedstuffs. J. Dairy Sci. 78:161-171.

Cummins, K. A., J. N. Nocek, C. E. Polan and J. H. Herbein. 1983. Nitrogen degradability and microbial protein synthesis in calves fed diets of varying degradability defined by the bag technique. J. Dairy Sci. 66: 2356-2364.

Çetinkaya, N., T. Bakioğlu, I. Tükenmez and S. Ünal. 1990. Calculation of rumen leaving rates of protein supplements by means of inert radioactive tracers. TAEK, 1st National Nucklear Agricultural and Animal Husbandry Congress, Van, 13-15. September.

Deniz, S. and Ş. D. Tuncer. 1995a. The effect of formaldehyde treated vegetable protein sources on degradability of dry matter and crude protein and effective protein in the remen. Tr. J. Vet. & Anim. Sci. 19:1-8.

Deniz, S. and Ş. D. Tuncer. 1995b. The effect of formaldehyde treated vegetable protein sources on degradability of nutrients and some blood and ruminal metabolites. Tr. J. Vet. & Anim. Sci. 19:1-8.

Düzgünes, O., T. Kesici, O. Kavuncu and F. Gürbüz. 1987. Research and trial methiods (Statistical Methiods II). Ank. Univ. Agr. Fac. Pub. 1021, Ankara.

Ensminger, M. E., J. E. Oldfield and W. W. Heinemann. 1990. Feeds and Nutrition (2nd Ed.) The Ensminger Comp., California.

Erasmus, L. J., P. M. Botha, C. W. Cruywagen and H. H. Meissner. 1994. Amino acid profile and intestinal digestibility in dairy cows of rumen-undegradable protein from various feedstuffs. J. Dairy Sci. 77:541-551.

Goedeken, F. K., T. J. Klopfenstein, R. A. Stock and R. A. Britton. 1990. Hydrolyzed feather meal as a protein source for growing calves. J. Anim. Sci. 68:2945-2953.

Klopfenstein, T. J., R. A. Stock and R. A. Britton. 1985. Relevance of bypass protein to cattle feeding. Professional Anim. Sci. 1:27-31.

Loerch, S. C., L. L. Berger, D. Gianola and G. C. Fahey, Jr. 1983a. Effects of dietary protein source and energy level on in situ nitrogen disappearance of various protein sources. J. Anim. Sci. 56:206-216.

Loerch, S. C., L. L. Berger, S. D. Plegge and G. C. Fahey, Jr. 1983b. Digestibility and rumen escape of soybean meal, blood meal, meat and bone meal and dehydrated alfalfa nitrogen. J. Anim. Sci. 56:1037-1047.

MacDonald, P., R. A. Edwards and J. D. F. Greenhalgh. 1987. Animal Nutrition. 4th. ed. Logman, London and New York.

Madsen, J. and T. Hvelplund. 1994. Prediction of *in situ* protein degradability in the rumen. Results of a European ringtest. Livestock Prod. Sci. 39: 201-212.

Matras, J., S. J. Bartle and R. L. Preston. 1990. Effects of ruminal escape proteins and canola meal on nitrogen utilization by growing lambs. J. Anim. Sci. 68:2547-2554.

Matras, J., S. J. Bartle and R. L. Preston. 1991. Nitrogen utilization in growing lambs: Effects of grain (starch) and protein sources with various rates of ruminal degradation. J. Anim. Sci. 69:339-347.

Merchen, N. R., D. E. Darden, L. L. Berger, G. C. Fahey, Jr., E. C. Titgemeyer and R. L. Fermando. 1987. Effects of dietary energy level and supplemental protein source on performance of growing steers and nutrient digestibility and nitrogen balance in lambs. J. Anim. Sci. 65:658-668.

Mir, Z., G. K. MacLeod, J. G. Buchanan-Smith, D. G. Grieve and W. L. Grovum. 1984. Methods for protecting soybean and canola proteins from degradation in the rumen. Can. J. Anim. Sci. 64:853-865.

Ocak, N., G. Erener and B. Z. Sariçiçek. 1994. Hazelnut kernel oil meal as a protein source. Feed Magazine. 2:18-22.

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. Agric. Sci. Camb. 92:499-503.

Ørskov, E. R. 1992. Protein Nutrition in Ruminants Utilizing Hazelnut Kernel Oil Meal in Layer Diets (2nd Ed.). Academic Press, London,

Owens, F. N. and W. G. Bergen. 1983. Nitrogen metabolism of ruminant animals: Historical perspective, current understanding and future implications. J. Anim. Sci.

57(Suppl. 2):498-518.

Özen, N. and G. Erener. 1992. Utilizing hazelnut kernel oil meal in layer diets. Poult. Sci. 71:570-573.

Preston, T. K. 1985. Better utilization of crop residues and byproducts in animal feeding research guidelines. 2. A practical manual for research workers. FAO Animal Production and Health Paper 50/2, Rome.

Santos, K. A., M. D. Stern and L. D. Satter. 1984. Protein degradation in the rumen and amino acid absorption in the small intestine of lactating dairy cattle fed various protein sources. J. Anim. Sci. 58:244-255.

Sehgal, J. P. and G. S. Marker. 1994. Protein evaluation in ruminants *in vitro*, *in sacco*, *in vivo* protein degradability and microbial efficiency of different protein supplements in growing buffalo calves. Animal Feed Sci. 45:149-165.

Stern, M. D. and L. D. Satter. 1984. Evaluation of nitrogen solubility and the Dacron bag technique as methods for estimating protein degradability in the rumen. J. Anim. Sci. 58:714-724.

Van Straalen, W. M., F. M. H. Dooper, A. M. Antoniewicz, I. Kosmala and A. V. Van Vuuren. 1993. Intestinal digestibility of protein from grass and clover in dairy cows measured with the mobile nylon bag and other methods. J. Dairy Sci. 76:2970-2979.

Weakley, D. C., F. N. Owens and W. L. Stockland. 1984. Soybean meal digestion in the rumen. J. Anim. Sci. 59 (Suppl. 1):410(Abstr.).