Effects of Protein Supplement Sources on Digestibility of Nutrients, Balance of Nitrogen and Energy in Goats and Their *In Situ* Degradability in Cattle

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ABSTRACT : The experiment was conducted to determine *in situ* rumen degradability of soybean meal (SM), fish meal (FM), sesame cake (SC) and Italian ryegrass hay (IRGH) and the effect of supplementing the above protein meals to IRGH on digestibility and balance of nutrients in three Saanen goats. For measuring the degradability, nylon bags containing each meal were incubated in the rumen of one fistulated dry cow for 3, 6, 12, 24, 36, and 48 hrs. Degradability revealed that SM protein was highly degradable in the rumen (99.1%), while FM protein was less degradable (76.8%) with SC protein being intermediate (91.2%) at 48 hrs of incubation ($p < 0.01$). Degradation rate of the potentially degradable fraction was estimated to be 12.12, 5.88 and 5.88%/hr for SM, FM and SC, respectively. In the metabolism trial, all goats were offered daily 900 g IRGH and one of the supplements, SM (100 g), FM (75 g) or SC (100 g). Intake of DM, OM, CP and GE was similar among diets. However, digestibility of OM for SC diet was significantly lower than that for diets supplemented with FM and SM ($p < 0.10$). Nitrogen (N) excreted in faeces ($p < 0.05$) and in urine ($p < 0.10$) was, respectively, higher and lower for SC diet than that for the other two diets. The same tendency was observed in energy losses in faeces ($p < 0.10$) and in urine ($p < 0.05$). There was no difference in energy loss in methane or in heat production among diets. Consequently, no significant difference was observed in N retention (2.13, 0.42 and −0.11 g/day for FM, SC and SM diet, respectively) or in energy retention (−1.49, −2.14 and −2.70 MJ/day for FM, SM and SC diet, respectively). These results showed that protein supplements affected the digestion of diets based on grass hay with 7.45% CP in DM in goats, although there was no significant influence on N or energy retention.
(Key Words: Soybean Meal, Fish Meal, Sesame Cake, Rumen Degradation, Nutrient Utilization, Goats)

INTRODUCTION

Goats play an important role in livestock production systems in tropical countries. However, the major constraint in improving productivity of goats is their poor nutritional status. Several workers reported that diet supplementation with protein and energy improved nitrogen retention and feed utilization, specially in rations based on low quality roughages (Verma and Mudgal, 1971; Krishna and Ranjhan, 1985). Gibson (1981) stated that diets containing concentrates improved animal performance through a more uniform pattern of fermentation in the rumen.

Nutrient utilization in ruminants is influenced by various factors associated with their productive status. A significant part of the dietary protein is degraded in the rumen and utilized for microbial protein synthesis. Protein source and degradation in the rumen may have an important influence on amino acid quantities and qualities reaching tissues and organs of ruminants and consequently affect their overall performance (Van der Aar et al., 1984). The nylon bag technique has been recommended to study the degradation pattern of feedstuffs in an attempt to manipulate rumen ecosystem for improved protein utilization (Gangadhar et al., 1993).

Therefore, information on ruminal protein degradability and degradation characteristics is very much required in formulating rations. Few studies have been carried out on the effect of dietary protein and its extent of ruminal degradation on body weight, and protein and energy deposition in goats. The objective of the present study was to determine : 1) ruminal degradation of dry

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consecutive days. The chamber (Iwasaki et al., 1982) was maintained under controlled condition of temperature (20℃) and relative humidity (60%) throughout the measurement period. Metabolizable energy (ME) intake, heat production (HP), and energy balance (EB) were calculated using the following formulae (Brouwer, 1965).

ME (k joule/day) = feed E − faeces E − urine E − methane E

HP (k joule/day) = $16.18 \times O_2(l) + 5.02 \times CO_2(l) - 2.17 \times CH_4(l) - 5.99 \times$ N (g in urine)

EB (k joule/day) = ME − HP

Blood sampling

At the end of each period, blood samples from all goats were collected from the jugular vein before feeding. Vacutainers contained heparin sodium as anticoagulant.

Chemical analysis

Analyses of feeds, residues and faeces were determined according to AOAC (1990). Fresh faeces and urine were analysed for N using Kjeldhal apparatus. Gross energy was determined by a bomb calorimeter (Yoshida Seisakusho Co., Ltd., Japan). Analysis kits (Wako Pure Chemical Industries, Ltd., Japan) were used for measuring plasma glucose, urea-N and non-esterified fatty acids (NEFA).

Statistical analysis

Results of feed intake, digestibility, balance trial and blood components were analysed statistically as a 3×3 Latin Square by analysis of variance (Steel and Torrie, 1960). The differences among means were tested according to the LSD method.

RESULTS AND DISCUSSION

Chemical composition

Chemical composition of feed ingredients is given in table 1. We see that among protein sources, FM had the highest total ash and ether extract (EE) but lowest crude fibre (CF) content. On the other hand, SC had the highest CF but lowest EE content. Soybean meal was the highest in nitrogen free extract (NFE). However, GE of protein sources was quite similar.

Table 1. Chemical composition and energy value of feed ingredients (% on air dry basis)

Component	Soybean meal (SM)	Fish meal (FM)	Sesame cake (SC)	Italian ryegrass hay (IRGH)
Dry matter (DM)	89.64	89.53	91.08	89.68
Organic matter (OM)	83.52	72.79	78.61	82.12
Crude protein (CP)	43.14	61.47	48.39	7.45
Ether extract (EE)	2.43	7.02	1.66	2.06
Crude fibre (CF)	6.23	1.41	9.68	28.11
Nitrogen free extract (NFE)	31.72	2.89	18.88	44.50
Total ash	6.12	16.74	12.47	7.56
Gross energy (GE) (kJ/g)	17.96	18.26	17.81	16.30

Rumen degradation

The pattern of DM disappearance over incubation time was different among protein feeds (figure 1). Dry matter disappearance of protein feeds revealed that SM was highly degradable, followed by SC and then FM. At 48 hrs of incubation, DM degradability was 98.7, 88.5 and 67.0% for SM, SC and FM, respectively ($p < 0.01$). The highest DM degradability of SM at all incubation time indicates that SM is more susceptible to microbial attack in comparison to other protein sources. Similar differences in DM degradation of protein feeds were reported by Kumar and Walli (1989). Dry matter degradability of IRGH was 59.5 and 68.4% at 48 and 72 hrs of incubation, respectively. Lower *in situ* DM degradability for IRGH in comparison to protein feeds is due to longer lag phase (Chesson and Ørskov, 1984). Bacteria attachment to the surface of substrates and subsequent formation of colonies does not occur simultaneously in most fibrous feeds, hence resulting in lower digestion. Dry matter degradability observed in the present experiment corresponds well with the findings of Chaturvedi and Walli (1995).

Differences in CP disappearance were also observed among protein feeds for all incubation intervals (figure 2). At 48 hrs of incubation, CP degradability was 99.1, 91.2 and 76.8% for SM, SC and FM, respectively ($p < 0.01$).

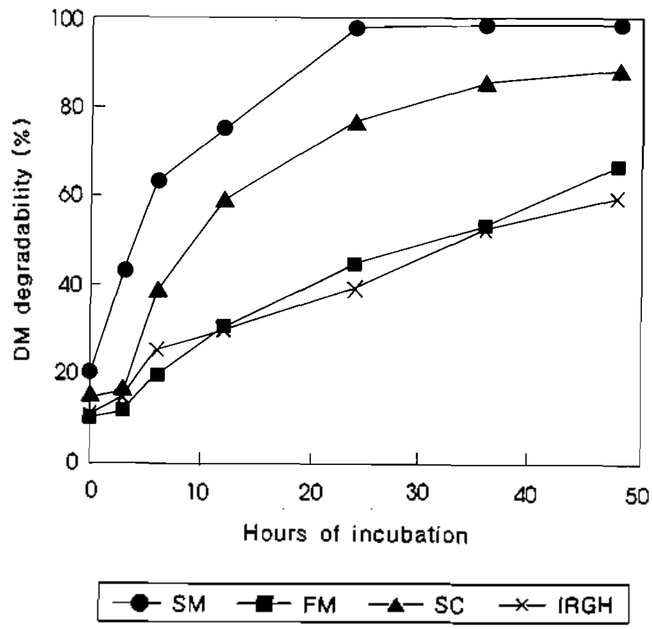

Figure 1. DM degradability of protein meals and grass hay.

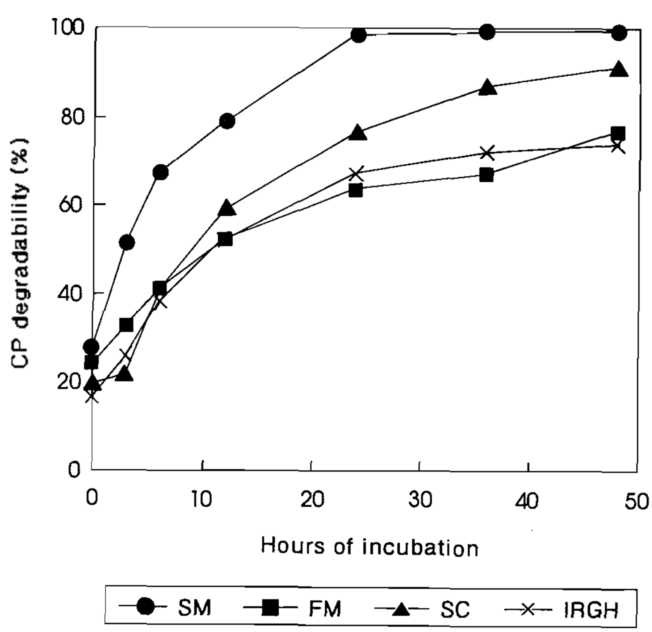

Figure 2. CP degradability of protein meals and grass hay.

Crude protein degradability of SM reached 98.5% at 24 hrs of incubation, indicating that CP of SM is highly degradable. On the other hand, CP degradability of FM was low, suggesting that the undegradable fraction of FM protein is high. Crude protein degradability of SC was intermediate to that of SM and FM. In the first few hours of incubation, degradation of SC was very slow even when compared to that of FM, which could be due to its high CF content. Crude protein degradability of IRGH also was high, 74.0 and 78.9% at 48 and 72 hrs of incubation, respectively, and consistent with the values reported by Khandaker and Tareque (1996) and Prakash et al. (1996).

Kinetic analysis of CP degradation (table 2) showed that a soluble fraction (a) of SM was significantly higher than that of SC ($p < 0.05$). A potentially degradable fraction (b) of SC and SM was significantly higher than that of FM ($p < 0.05$) and degradation rate of this fraction (k) of SM was significantly higher than that of FM and SC ($p < 0.05$). These results indicate quite different properties of CP among these protein supplements, with effective degradability being higher for SM, followed by SC and then FM.

Nutrient utilization

All goats consumed their protein feeds and almost all grass hay, except for one goat that left a considerable amount of protein feed (69 g/d) when SC was fed. Average DM intake did not differ significantly ($p > 0.10$) among dietary treatments. Intake of DM by goats in this experiment is comparable to values observed by other researchers (Kishan et al., 1981 ; Virk et al., 1991). There was no significant difference in DM digestibility among diets ($p > 0.10$). However, OM digestibility of SC diet was significantly lower than that of FM and SM ($p < 0.10$) (table 3). Similar DM digestibility was reported in goats fed mixed grass hay with protein feeds (Reddy and Raghaven, 1987) and in sheep (Nitas et al., 1997).

Intake of CP or N did not differ significantly ($p > 0.10$) among dietary treatments (table 3). However, CP digestibility and N excretion in faeces were, respectively, lower ($p < 0.05$) and higher ($p < 0.05$) for SC diet than those for FM and SM. Lower CP digestibility of SC diet could probably be attributed to the low CP digestibility of SC itself as intake of IRGH was similar among diets, although potentially degradable protein of SC in the rumen was observed to be high (table 2). Higher CP digestibility of FM diet and lower CP degradation of FM in the rumen indicate that high digestibility of escaped protein of FM in the intestines. On the other hand, N excretion in urine was significantly lower for SC diet than that for FM and SM ($p < 0.10$). As a result, N retention was + 2.1, + 0.4 and −0.1 g/day for goats supplemented with FM, SC and SM, respectively, although differences were not significant ($p > 0.10$). Better N utilization in goats fed FM might be partly attributable to greater intake of digestible OM, which would lead to effective

Table 2. Degradation kinetics of crude protein in the rumen for protein supplements and Italian ryegrass hay measured by the nylon bag technique

	Soybean meal (SM)	Fish meal (FM)	Sesame cake (SC)	Italian ryegrass hay (IRGH)
Degradation characteristics (%)				
a	28.41^{A}	24.85^{AB}	16.10^{B}	16.00
b	71.49^{A}	52.13^{B}	80.38^{A}	61.55
k (%/hr)	12.12^{A}	5.88^{B}	5.88^{B}	7.21
residual SD	2.81	2.50	4.20	1.53
Effective degradability (%) out flow rate (p), (%/hr)				
2.0	–	–	–	49.92
4.0	55.51	33.54	49.47	41.01
6.0	49.39	27.89	41.14	–

Degradability = $a + b\,(1 - e^{-kt})$.
Effective degradability = $(a + bk)/(k + p)$.
Means in the same row with different superscripts are significantly different ($p < 0.05$).

Table 3. Digestibility of nutrients and balance of nitrogen and energy in goats fed on diets supplemented with different protein feeds

	Diets supplemented with			SE	Probability
	Soybean meal (SM)	Fish meal (FM)	Sesame cake (SC)		
Digestibility					
DM (%)	53.93	56.39	46.98	1.73	NS
OM (%)	55.49^{a}	58.40^{a}	48.85^{b}	1.58	0.10
CP (%)	64.01^{A}	68.46^{A}	48.01^{B}	1.74	0.05
EE (%)	62.09^{b}	70.21^{a}	58.12^{b}	1.95	0.10
CF (%)	44.72	50.01	40.05	2.43	NS
NFE (%)	59.43	60.14	53.87	1.18	NS
GE (%)	53.05	56.19	45.64	2.10	NS
Nitrogen balance					
Total N intake (g/d)	17.62	18.10	16.85	0.93	NS
N excretion (g/d)					
Faeces	6.35^{B}	5.70^{B}	8.60^{A}	0.30	0.05
Urine	11.38^{a}	10.26^{a}	7.84^{b}	0.45	0.10
Total	17.73	15.96	16.44		
N retention (g/d)	−0.11	+2.13	+0.42	0.66	NS
Energy balance					
GE intake (MJ/d)	16.46	16.04	16.03	0.24	NS
Energy excretion (MJ/d)					
Faeces	7.73^{b}	7.03^{b}	8.68^{a}	0.20	0.10
Urine	1.59^{A}	1.45^{A}	1.19^{B}	0.032	0.05
Methane	1.10	1.03	1.03	0.016	NS
Heat production	8.17	8.02	7.83	0.11	NS
Total	18.59	17.53	18.73		
Energy retention (MJ/d)	−2.14	−1.49	−2.70	0.43	NS

NS ; $p > 0.10$, 0.10 ; $p < 0.10$, 0.05 ; $p < 0.05$.
Means in the same row with different superscripts are significantly different (A, B ; $p < 0.05$, a, b ; $p < 0.10$).

conversion of ruminal ammonia to microbial protein. Mean daily N retention in the present experiment are similar to those reported by Zebrowska et al. (1992).

Intake of GE was similar among dietary treatments (table 3). However, energy losses in faeces and in urine were, respectively, higher ($p < 0.10$) and lower ($p < 0.05$) for SC diet than those for FM and SM. There were no significant differences ($p > 0.10$) in methane and in heat production among diets. As a result, energy retention was −1.5, −2.1 and −2.7 MJ/day for goats supplemented with FM, SM and SC, respectively. Better energy utilization was observed for goats fed FM, although differences were not significant ($p > 0.10$).

Blood components

Plasma concentration of glucose, NEFA, and urea-N were averaged, respectively, 63.3, 60.3, 59.2 mg/dl, 0.487, 0.394, 0.456 mEq/l, and 40.1, 26.1, 21.5 mg/dl (for goats fed SM, FM, SC, respectively) and were not different significantly ($p > 0.10$) among dietary treatments. In the present experiment, blood samples were taken prior to morning feeding of goats, and, according to Hove and Halse (1983), sampling is very important, as prior to morning feed, absorption of nutrients from the digestive tract was at minimum level. This may be the possible reason for the lack of differences among diets in the present experiment.

CONCLUSION

Under conditions of this experiment, protein supplements affected the utilization of N and energy in diets based on grass hay in goats, indicating the importance of selecting protein sources for increased feed efficiency. Fish meal was an optimal protein supplement to hay, which provided highly digestible escaped protein to the intestines. Soybean meal was highly degradable in the rumen, resulting in increased urinary N loss. Sesame cake was less digestable and brought lower digestion of OM, CP and GE.

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