Estimation of Ruminal Degradation and Intestinal Availability of Crude Protein in the Animal-Origin Feedstuffs Using Mobile Nylon Bag Technique

S. C. Lee and Y. H. Moon[1]
National Livestock Research Institute, Rural Development Administration, Korea

ABSTRACT : Ruminal degradation characteristics and intestinal availability of crude protein (CP) in four animal-origin feeds (fish meal, meat meal, viscera meal, feather meal) were estimated by mobile nylon bag technique. Three ruminally and duodenally cannulated Holstein dairy cows (average body wt. 550kg) fed a diet containing 40% concentrate and 60% orchard grass hay on a dry matter (DM) basis.

Assuming that the outflow rate of diet in rumen is 5% per hour (k = 0.05), contents of quickly degradable CP (QDP), slowly degradable CP(SDP), and undegradable CP (UDP) in the rumen were 27.6%, 9.4%, 63.0% for fish meal, 34.3%, 28.1%, 37.6% for meat meal, 43.9%, 12.5%, 43.6% for viscera meal, and 14.4%, 15.8%, 69.8% for feather meal, respectively.

Intestinal CP degradability was 51.0% for fish meal, 27.2% for meat meal, 37.9% for viscera meal and 56.2% for feather meal.

Available UDP in the intestinal tract was contained 288 g, 217 g, 246 g and 423 g per kilograme DM of diet in fish meal, meat meal, viscera meal and feather meal, respectively.

(**Key Words**: Fish Meal, Meat Meal, Viscera Meal, Feather Meal, Mobile Nylon Bag, Undegradable Crude Protein, Intestinal Availability)

INTRODUCTION

Because rapidly growing or lactating ruminants with high milk production require an amino acid supply in addition to that produced by ruminal microbes, animals in these cases should be sufficiently allowed for intestinal available protein in ration.

Prevention of degradation in the rumen may be useful in case of feeds high in protein. However rich one may have protein protected in the rumen, it is useless or on the contrary a loss that not being digest in the lower gastro-intestinal tract. And therefore, in order to calculate the absorption of rumen undegraded protein (UDP) from the small intestine, estimation of the digestibility of UDP is required. For the estimation of intestinal digestibility of UDP a mobile nylon bag technique for ruminant was initially introduced by Kirkpatrick and Kennelly (1984). These informations by mobile nylon bag technique may permit ration formulation on the basis of available UDP.

Although animal by-products is their high moisture content, the majority of animal waste material, unlike plant waste, has a high content of digestible protein and energy in dry matter. And owing to low degradability in the rumen, animal-origin feeds may be supplied the high quality protein to ruminant.

The objectives of this study were to estimate the *in situ* ruminal CP degradation kinetics and the intestinal availability of UDP for four animal-origin feeds using mobile nylon bag technique.

MATERIALS AND METHODS

Animals and diets

Three ruminally and duodenally (T-type) cannulated dry Holstein cows (average body wt. 550 kg) were fed a diet containing 40% concentrate and 60% orchard grass hay on a dry matter basis twice daily (07:30 and 19:30) by 110% of NRC (1988) requirements for maintenance. Animals were available to water and mineral block.

Four animal-origin feeds (fish meal, meat meal, viscera meal, feather meal) obtained commercially were used for estimation of *in situ* degradabilities of nutrients in each digestive tracts of cow, and were ground by wiley mill with a 1-mm screen.

In situ measurements

The *in situ* rumen and intestinal degradabilities for four animal-origin feeds were measured using mobile nylon bag technique (de Boer et al., 1987). The nylon

[1] Address reprint requests to Y. H. Moon, Department of Dairy Science, Chinju National University, Chinju, Republic of Korea, 660-280.
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texture (pore size 45 μm) was purchased from Swiss Screen Co.

Large bag (LB) for ruminal degradability were cut to an internal size 9.0 × 15 cm and were double stitched with curved corners and closed off at the top with a nylon drawstring. 5 g sample of test feed was inserted into the LB. In order to place the bags in the dorsal sac of reticulorumen of each cow, a glass bead of about 2 g was put into the each LB and weighed. For ruminal degradation kinetics of feedstuffs, three LB were removed from the rumens of the three cows after suspension of 0, 1, 2, 4, 6, 8, 12 and 16 hours, respectively.

For intestinal degradability, small bag (SB) were cut into 7.0 × 5.5 cm pieces and folded in half. SB were formed 3 mm from each of two free edges by heat sealing machine, and after inserting the sample of 1 g into the SB were heat sealed (3.5 × 2.5 cm, final dimensions). Both LB and SB containing the test feed were placed into a polyester mesh bag having a nylong string (75 cm long), and a nylon string connected to the outside of the cannula.

Just before insertion in the rumen, nylon bags with feed samples were presoaked for 5 min in 39℃ water, and were placed in cows just after 07:30 feeding. Two LB per feed sample were removed for 0 hr incubation sample.

SB was incubated in the rumen for 16 hour, thereafter passed to the lower tract through duodenal cannula by intervals of 30 min with 9 replications (3 animals × 3 bags). SB not inserted immediately the duodenum after rumen withdrawal were kept at 4℃. SB inserted into the intestine to determine intestinal availability were not washed after rumen incubation. SB was recovered from feces at 12-14 hrs after insertion into the duodenum through cannula.

LB and SB incubated were mechanically (particularly deviced machine washer) rinsed in cold water until the rinse water was clear, it took about 30 min. The rinsed bags were dried in a forced air oven set at 70℃ for 48 hr, desiccated, and weighed. Residues of the bags for each animal and each incubation time were placed individually in heat sealed vinyl bag and stored for later analysis. The nitrogen contents in bag residues measured by automatic Kjeldahl (Kjeltec Auto 1,035 Analyzer/1,038 Sampler, Tecator, Sweden).

Data analysis

The feed protein degradation kinetics were fitted to an exponential type model as follows (Ørskov and McDonald, 1979)

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

where, "P" is percentage disappearance at time "t" suspended in the rumen, "a" is the intercept of the degradation curve on the y-axis (solubility), "b" is the curve asymptot at infinite time, and "c" is the instaneous rate of change of degradation.

Estimated values of "a", "b", and "c" were derived from a nonlinear, iterative, least squares Marquardt (1963) procedure using SAS (SAS Institute, 1985).

Effective degradability (ED) where fractional outflow rate (k) is accounted for its effect on degradability was also estimated by the equation of Ørskov and McDonald (1979). Three functional outflow rates of 0.02, 0.05 and 0.08/hr were assumed as proposed by ARC (1984). In this study, outflow rate (k) of 0.05 was applied to the estimated values of quickly degradable crude protein (QDP), slowly degradable crude protein (SDP) and undegradable crude protein (UDP) in the rumen (AFRC, 1993). From parameters (a, b, c) of above non-linear equation ED, QDP, SDP and UDP were calculated as follows.

$$ED = a + (b \times c)/(c + k)$$
$$QDP = a \times [CP]$$
$$SDP = \{(b \times c)/(c + 0.05)\} \times [CP]$$
$$UDP = [CP] - \{[QDP] + [SDP]\}$$

Whole digestive tract (rumen plus intestine) disappearence of nutrient was obtained from the trial using SB, and intestinal disappearence was calculated by subtracting the rumen disappearence (%) from whole digestive tract disappearence (%). In this case, rumen disappearence was used the ED at 0.05 of out flow rate. Intestinal availability of rumen undegraded crude protein (A-UDP) was calculated as :

A−UDP = (UDP−CP residue after rumen plus intestinal incubation)/UDP

Statistical analysis

Analysis of the variance was performed on data using the SAS general linear models procedure as a randomized block design with cow acting as the replicate. Data are expressed as least square means, with differences among means were compared by least significant difference (SAS Institute, 1988).

RESULTS AND DISCUSSION

Chemical composition of feeds

Chemical composition of experimental feeds analyzed with three replications was presented in table 1. Experimental feeds contained approximately 5.9-13.0% moisture, which was in range of the 12% (maximum 14%) recommended for safe storage (Snyder and Kwon, 1987).

Table 1. Chemical composition of animal-origin feeds

Items	Fish meal	Meat meal	Viscera meal	Feather meal
	..... % DM			
DM	93.72[a]	92.02[a]	90.15[ab]	86.98[b]
CP	56.47[d]	79.83[a]	64.94[c]	75.42[b]
EE[1)]	15.96[b]	15.32[b]	20.49[a]	16.28[b]
CF[2)]	0.31[b]	0.97[a]	1.32[a]	0.56[ab]
Ash	4.39[c]	7.95[b]	13.11[a]	7.76[b]

[a,b,c,d] Means with different superscripts in the same row differ ($p < 0.05$).
[1)] Ether extract.
[2)] Crude fiber.

Crude protein contents were 56.5% for fish meal, 79.8 % for meat meal, 64.9% for viscera meal, and 75.4% for feather meal.

Crude ash content was significantly ($p < 0.05$) higher in viscera meal compare to the other feeds.

CP degradation kinetics in the rumen

Ruminal CP degradation characteristics of four animal-origin feeds were presented in table 2.

"b" fraction of meat meal was fastly degraded as a 22.4 % per hour, intermediate for fish meal (8.9%/hr) and viscera meal (7.9%/hr), and slowest for feather meal (2.9% /hr).

ED of dietary CP in the rumen was higher in the order of meat meal, viscera meal, fish meal, and feather meal, but was not different between meat meal and viscera meal, and between fish meal and feather meal, respectively.

QDP content of experimental feedstuffs was higher in the order of viscera meal, meat meal, fish meal and feather meal. SDP was highest for meat meal, intermediate for viscera meal and feather meal, and lowest for fish meal. UDP content was extremely high in feather meal and fish meal, and was relatively low in meat meal and viscera meal.

NRC(1988) reported that contents of UDP were 60% for fish meal, 78% for well-preserved fish meal, 76% for meat meal, and 71% for hydrolyzed feather meal. Although UDP content of meat meal was remarkably higher compare to that of our study, those of fish meal and feather meal were in similar extent of levels. The composition and the structure of feed protein have been suggested to be the main reasons for the differences of degradability between feedstuffs. Mahadevan et al. (1980) suggested that disulfide bond in feed protein indicate a low degradability of protein in the rumen. Therefore in the group of special feeds, such as feather meal and meat meal, protein degradation can be decreased also by the high content of hair in the meal (Stock et al., 1981), due to abundance of disulfide bond in hair. Because the meat meal used in this study, however, did not contained hair, ruminal CP degradability was comparatively high.

Table 2. Ruminal *in situ* crude protein degradation for animal-origin feeds

Items	Fish meal	Meat meal	Viscera meal	Feather meal	SEM[6)]
Parameters[1)]					
a	27.57[c]	34.30[b]	43.87[a]	14.39[d]	1.35
b	14.70[d]	34.35[b]	20.39[c]	42.99[a]	3.02
c	0.089[b]	0.224[a]	0.079[b]	0.029[c]	0.01
ED[2)]					
k = .02	39.57[b]	65.83[a]	60.14[a]	39.83[b]	2.12
k = .05	36.98[b]	62.38[a]	56.36[a]	30.17[b]	1.89
k = .08	35.31[b]	59.61[a]	54.00[a]	25.83[c]	2.02
QDP[3)]	27.57[c]	34.30[b]	43.87[a]	14.39[d]	2.86
SDP[4)]	9.40[c]	28.08[a]	12.49[b]	15.78[b]	2.11
UDP[5)]	63.02[a]	37.62[b]	43.64[b]	69.84[a]	2.99

[1)] a,b,c = Fitted exponential constants for crude protein.
[2)] Effective degradability of crude protein at rates of passage(k) of 0.02, 0.05 and 0.08% DM basis.
[3)] Quickly degradable crude protein at k = 0.05, % DM basis.
[4)] Slowly degradable crude protein at k = 0.05, % DM basis.
[5)] Undegradable crude protein at k = 0.05, % DM basis.
[6)] Standard error of the mean.
[a,b,c,d] Means with different superscript in the same row differ ($p < 0.05$).

Intestinal and whole digestive tract CP degradation coefficients of four animal-origin feeds were presented in table 3.

Intestinal CP degradability was higher in the order of feather meal, fish meal, viscera meal and meat meal, which was contradictory results with ruminal CP degradability. Protein source with a low ruminal protein degradation is regard that may enhance animal performance due to incerease of the amount available protein for intestinal digestion by the host animal. But it

is necessary to estimate the intestinal availability of rumen undegraded protein (A-UDP) since low ruminal degradability is not always accord with high intestinal availability. In this study, A-UDP was highest for viscera meal, intermediate for feather meal and fish meal, and lowest for meat meal.

Table 3. Crude protein degradation of animal-origin feeds in digestive tracts of dairy cattle

Items	Fish meal	Meat meal	Viscera meal	Feather meal	SEM[3]
Digestive tract	.....	% DM	.....		
Rumen[1]	36.98[c]	62.38[a]	56.36[b]	30.17[d]	2.92
Intestine	50.98[b]	27.24[d]	37.92[c]	56.17[a]	1.90
Whole tract	87.96[b]	89.62[b]	94.28[a]	86.34[b]	0.80
A-UDP[2]	80.89[b]	72.41[c]	86.89[a]	80.44[b]	1.91

[1] Effective degradability at k = 0.05.
[2] Intestinal availability of rumen undegraded crude protein.
[3] Standard error of the mean.
[a,b,c,d] Means with different superscripts in the same row differ ($p < 0.05$).

Van Straalen and Tamminga (1990) reported that protein availabilities in intestine for fish meal and meat meal were 92% and 72%, respectively. Their result for meat meal was similar extent with our's, but that for fish meal was remarkably higher as much as about 14%. This difference of intestinal availability could be originated from the quality of fish meal used.

Dietary CP degradaded through the whole digestive tract was highest in viscera meal, but no differences were observed among fish meal, meat meal and feather meal. High degradability in the whole digestive tract related to washing of nylon bags subsequent to their collection from feces as opposed to wiping fecal material from the surface of the bag (Kirkpatrick and Kennelly, 1984). As washing tends to remove endogenous and bacterial contamination of bags, de Boer et al. (1987) mentioned that whole digestive tract degradability measured, using the mobile nylon bag technique described in this study, can be considered as an estimate of true, rather than apparent, digestibility.

In conclusion, the amount of CP degradation per kilograme of four animal-origin feeds in digestive tracts of dairy cattle were summarized as table 4.

UDP and CP disappeared in intestine were remarkably greater in feather meal compared to other feedstuffs. Amount of available CP in intestine was 288 g for fish meal, 217 g for meat meal, 246 g for viscera meal, and 423 g for feather meal per kilograme on a dry matter basis.

CP disappeared through the whole digestive tract was greatest for meat meal, and smallest for fish meal. Unavailable CP in digestive tract of dairy cow was greater in feather meal than in other feedstuffs.

Although there is very little experience with feather meal in dairy cattle rations, adding the feather meal in ruminant ration should be restrictively allowed (gradually at a rate of up to 0.7 kg per day) because of low palatability and CP digestibility in the whole digestive tract (Macgregor, 1989). However, in this study feather meal having a relatively high CP degradability in the whole digestive tract as well as a large amount of the available CP in intestine may be useful as a protein source for quickly growing or high yielding ruminants which was required much protein for production.

Table 4. Amounts of CP degradation of animal-origin feeds in digestive tracts of dairy cattle

Items	Fish meal	Meat meal	Viscera meal	Feather meal	SEM[1]
	.....	g/kg DM	.....		
CP	565	798	649	754	25.7
Rumen data					
QDP	156	274	285	109	26.8
SDP	53	224	81	119	18.2
UDP	356	300	283	526	24.5
Small bag data					
Intestinal disappearance	288	217	246	423	12.5
Whole tract disappearance	497	715	612	651	10.6
Unavailable CP	68	83	37	103	8.2

[1] Standard error of the mean.

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