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Studies on the protein degradabilities of feedstuffs in Taiwan

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Abstract

The protein degradabilities of feedstuffs, roughages and by-products that are commonly used in ruminant rations, were measured by the in situ nylon bag method.

Four dry dairy cows were fistulated in the rumen for the in situ nylon bag studies. Twenty-eight different feedstuff samples were placed in 4.5 × 6.5 cm nylon bags, and were then incubated in the rumen for different periods of time (0, 2, 4, 8, 12 and 24 h). Under 8% of rumen solid outflow rate, the percentages of the calculated protein degradability were: corn gluten meal, 8.8; feather meal, 29.1; soya pomace, 79.1; brewers grain, 37.1; distillers grain, 53.9; meat and bone meal, 51.9; wheat bran, 76.8; corn, 34.6, respectively. The size of nylon bag was changed to 10 × 20 cm, and the method of bag suspension was also changed, whilst the incubation period was extended two additional periods of 48 and 72 h in the second trial. The results of the protein degradabilities in 8% ruminal outflow rate were as follows: pangola hay. 38.6; soya pomace, 83.3; corn silage, 75.6; rice bran, 52.5; napier grass, 34.7; distillers grain, 60.1; brewers grain, 54.9; alfalfa hay, 71.8; fish meal, 37.5; soybean meal, 68.0; beancurd pomace, 61.7, respectively. All the degradabilities mentioned were uncorrected for influx microbial nitrogen.

From the smaller standard deviation of the crude protein disappearance rate in the large nylon bags (trial 2), it recommended the size of the nylon bags is 10 × 20 cm instead of 4.5 × 6.5 cm.

Keywords: Degradability; Protein; Feedstuffs; Dairy cattle

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1. Introduction

The crude protein system has been used as a standard for evaluation of the protein requirement of dairy cattle for years. This system is unable to cope with the protein requirement of high yielding dairy cattle during their peak performance period. Much literature shows no response to the increase of dietary crude protein levels in high performance dairy cattle. This increase may be due to the excess nitrogen in the rumen, which was derived from the breakdown of preformed dietary protein, and the ruminal nitrogen is beyond the maximal capability of the microbial mass to synthesis protein. Ruminants will metabolize the excess amount of ruminal ammonia through their liver via the bloodstream and discard the urea as urinary wastes. Elimination of this kind of waste is an important way to improve the production efficiency of dietary protein. A better system that can supply an adequate source of nitrogen for ruminal fermentation without wasting nitrogen resources has been developed. It can then provide an appropriate quantity of the protein that can bypass the rumen without being degraded. This kind of protein system cannot only supply nitrogen for maximum ruminal fermentation, but can also provide better metabolizable protein for high performance dairy cattle. NRC (1985) proposed an absorbed protein system for high performance dairy cattle. These systems included not only the total intake protein (IP), but also the degradability of the protein named undegraded intake protein (UIP) and degraded intake protein (DIP).

In the evaluation of protein degradation, techniques other than time and labor intensive in vivo estimates are desirable. The nylon bag in situ technique is the most promising approach that can provide rapid and reasonable estimates for a wide variety of feedstuffs, though the technique is subject to variables that can influence the result. These include the bag porosity, sample size to bag surface area, microbial contamination, diet, animal effect, preruminal incubation, the washing technique, particle size of the feedstuff, and the size of the nylon bag (Nocek, 1988).

The aim of this study is to establish protein degradabilities of the conventional ruminant feedstuffs in Taiwan, while the influence of the size of the nylon bag on the protein degradability is also investigated.

2. Materials and methods

2.1. Experimental animals and management

Four Holstein dry dairy cows averaging 600 kg of body weight were fistulated in the rumen. Cattle were placed in a pen of 50 m^2 cement floor pen with a holding stanchion inside. Cattle were fed a total mixed ration of 15 kg dry matter with an equal amount of concentrate and roughage (dry basis), and were fed equally divided twice a day. Ration formulation is presented in Table 1. After a 10-day adaptation period, cattle were fed six times with an evenly divided amount of feed every day. The feeding hours during the experimental period were as follows: 00.30 h, 04.30 h, 08.30 h, 12.30 h, 16.30 h, 20.30 h.

Table 1
Diet formulation in the trials

	%
Ingredients	
Pangola hay	50.0
Yellow corn	23.9
Soybean meal	12.25
Wheat bran	10.0
Limestone	1.0
Dicalcium phosphate	1.5
Salt	0.25
Premix [a]	0.1
Total	100.0
Calculated value	
Crude protein	10.5
Neutral detergent fiber	41.0
Acid detergent fiber	28.0
Calcium	0.7
Phosphorus	0.5
Net energy (Mcal kg^{-1})	1.3

[a] Premix components (each kg contain): Vitamin A. 10,000,000 IU; Vitamin E, 70,000 IU; Vitamin D, 1,600,000 IU; Fe, 50 g; Zn, 40 g; Mn, 40 g; Co, 0.1 g; Cu, 10 g; I, 0.5 g; Se, 0.1 g.

2.2. *Feedstuff samples*

The most commonly used feedstuffs for dairy cattle were collected from various locations in Taiwan. Samples of approximately 5 kg of dry matter were then dried in a 50 °C air-draw oven for 24–72 h. The length of oven dry period depended on the moisture content of the sample. Samples were then ground through a 2 mm mesh screen and were placed into the plastic bottles for in situ incubation. Name, origin and the international feed number of the feedstuffs are presented in Table 2. Due to the seasonal differences, samples were not available simultaneously, therefore number of feeds and feed samples were different between trials.

2.3. *Procedure for in situ incubation (trial 1)*

The procedure of ruminal incubation in this trial followed the method of DeBoer et al. (1987). A feedstuff sample of approximately 1 g was packed and sealed into 4.5 × 6.5 cm polyester bag (Ankom Co. Ltd., Spencerport, NY, USA). Pore size of the polyester was 53 ± 10 μm. This was verified by microscopic examination. Each sample of 24 replicates with six replications per animal were prepared into individual nylon bags for the assay. Before placing into the rumen for incubation, all sample bags were heat sealed, and placed in a 39 °C water bath for a 10 min presoak. Four replicate samples for each incubation time were placed into the four fistulated cows; Every feed sample of different replicate with exception of the 0 h samples were placed in five ruminal incubation periods; 2, 4, 8, 12 and 24 h, respectively. The four 0 h incubation

Table 2
Sources of feedstuffs and specification

Name	ABV	IFN [a]	CP%	Remark
Concentrates				
Corn gluten meal	CGM	5–28–241	66.03	Imported
Whole soybean	EWSB	5–04–608	35.97	Extruded
Fish meal	FM	5–	66.70	Chilean
Feather meal	FTM	5–03–795	84.91	Imported
Rice bran, defatted	DFRB	4–03–930	16.53	Thailand
Rice bran	RB	4–03–928	13.99	Local
Yellow corn	CN1	4–02–935	8.78	USA
Yellow corn	CN2	4–02–935	8.18	USA
Corn meal rolled	RCN	4–02–864	8.34	USA
Cotton seed meal	WCS	5–01–614	18.05	Imported
Meat and bone meal	MB	5–09–321	45.75	Imported
Wheat bran	WB	4–05–191	17.89	Local
Soybean meal	SBM	5–04–612	43.42	Solvent
Roughages				
Corn silage	CS1	3–02–912	8.18	Fall crop
Corn silage	CS2	3–02–912	8.96	corn added
Soiling corn	SC	2–02–906	11.28	
Alfalfa hay	AH	1–00–023	17.83	USA
Alfalfa cube	AC	1–00–022	14.22	Canada
Pangola grass	PG	2–03–493	5.86	40 cm crop
Pangola hay	PH	2–03–493	3.12	50 cm crop
Napier grass	NP	1–08–462	7.43	2 m crop
Bermuda hay	BH	1–00–703	5.68	Imported
Peanut vines	PNH	1–	10.21	Local
By–products				
Soya pomace	SP	5–	16.28	Local
Beancurd pomace	BCP	4–	21.34	Local
Brewers grain	BG	5–02–142	28.61	Local
Distillers grain	DG	5–04–374	16.98	Local
Black tea pomace	BTS		22.49	Local

[a] IFN: international feed number.

sample bags were directly rinsed with water only. Bags were packed into a special design plastic tube that was a 6.5 cm diameter and 30 cm long poriferous tube with 70 cm string connected to the rumen fistula. This installation was a modification of the Nocek et al. (1979) method. The bag and the tube are shown in Fig. 1. The sample bags were placed into the rumen on different periods and were withdrawn from the rumen simultaneously. This means that samples were placed into the rumen in reverse order, i.e., sample for the 24 h incubation was placed into the rumen first. Immediately after removal from the rumen, samples were put in ice-water to stop the microbial fermentation and were then mechanically washed with 14 l of water 1.5 min three times. Samples were then dried in the 60 °C air-draw oven for 48 h. Dried samples with nylon bags were individually placed into Kjeldahl jar for nitrogen analysis according to AOAC (1980). An analysis of the empty nylon bag was used as a blank.

2.4. Modified in situ procedure (trial 2)

The size of the nylon bag was changed from 4.5 × 6.5 cm to 10 × 20 cm, and the sample weight also increased from 1 g to 8 g of dry matter. Instead of placed bags into the poriferous tube, bags were strung into an iron ring of 450 g; the string ring was then connected to the rumen fistula by a 70 cm nylon cord that is as shown in Fig. 2.

The incubation period was also extended in the modified procedure, i.e., 48 and 72 h. Due to the increase in size of the samples, the volume of sample washing water in the laundry machine was also increased from 14 l to 50 l.

2.5. Calculation and statistical analysis

The actual degradation curve was calculated by iterative least squares procedure according to SAS (1985). This model was followed by Orskov and McDonald (1979) as follows:

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

P is the actual degradation of protein after time t. a is the intercept of the degradation curve at time zero. b is the potential degradability of the component of the slowly soluble protein less the soluble N, which will, in time, be degraded. c represents the constant of degradation rate b at t hours. t is incubation time.

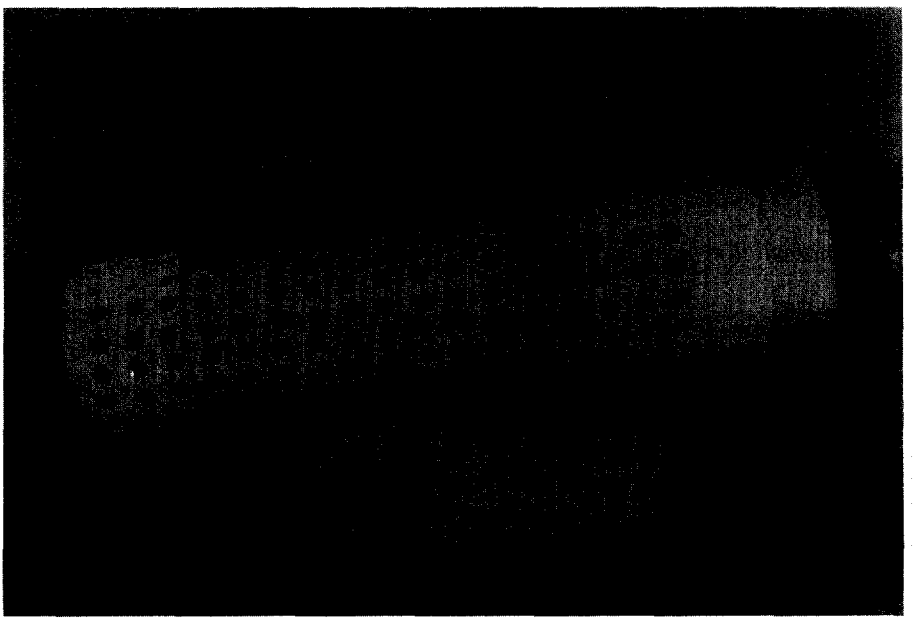

Fig. 1. Ruminal installation apparatus for in situ evaluation template with PVC tube and polyester bag.

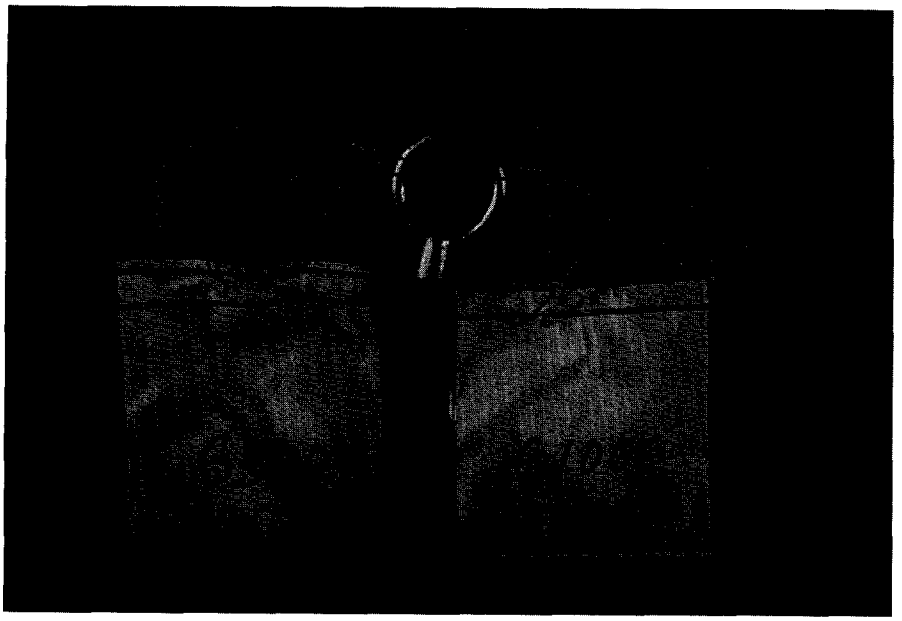

Fig. 2. Modified in situ evaluation template with iron weight and polyester bags.

Effective degradability of crude protein (EDCP) was calculated from the rumen outflow rate (k) and the constants a, b, and c from the above model. K is usually calculated on 0.02 h^{-1}, 0.05 h^{-1} or 0.08 h^{-1}. The EDCP formula is as follows:

$$EDCP = a + bc^{*}(c + k)^{-1}$$

Where k is the estimated rate of outflow from the rumen.

3. Results and discussion

3.1. Evaluation of protein degradabilities in trial 1

The crude protein disappearance rates of concentrates, forages or by-products are presented in Table 3. From the derived data, only nine out of 28 feedstuffs samples fit into the model of Orskov and McDonald (1979). The constants, a, b, c of the sample feedstuffs are presented in Table 4. These feedstuffs included corn gluten meal (CGM), feather meal (FTM), soya pomace (SP), brewers grain (BG), distillers grain (DG), wheat bran (WB), meat and bone meal (MB), corn No. 1 (CN1) and corn No. 2 (CN2). The calculated effective protein degradabilities of feedstuffs are also presented in Table 4.

Most of the crude protein disappearance of feedstuffs from nylon bags incubated in the rumen could not fit into the model of Orskov and McDonald (1979). Trends of protein disappearance at different incubation periods (Table 3) showed an irregularity in protein disappearance curves in 19 out of 28 samples. This means only 32% of the

Table 3
The percentage of crude protein disappearance from ruminal incubated feedstuffs in fistulated dairy cattle in trial 1

Feedstuffs	Incubation time, h					
	0	2	4	8	12	24
Concentrates						
CGM [b]	9.0	5.7 ± 1.7 [a]	6.8 ± 0.6	6.6 ± 0.2	9.3 ± 3.6	9.4 ± 3.1
EWSB	38.3 ± 24.8	16.6 ± 1.1	20.0 ± 0.9	33.9 ± 5.4	33.9 ± 3.9	71.3 ± 11.8
FM	27.2 ± 0.9	45.2 ± 5.6	32.0 ± 3.0	34.5 ± 6.4	34.1 ± 3.6	43.4 ± 3.8
FTM	18.1	24.9 ± 0.9	26.2 ± 0.4	30.0 ± 1.0	31.8 ± 3.4	31.5 ± 2.7
DFRB	23.6 ± 0.9	39.2 ± 4.7	44.6 ± 3.2	49.6 ± 5.8	67.6 ± 7.7	
RB	45.9	50.5 ± 0.7	51.5 ± 7.1	60.5 ± 3.9	65.7 ± 1.9	78.6 ± 1.8
CN1	28.0 ± 1.5	29.6 ± 3.1	29.8 ± 4.3	40.2 ± 7.7	37.0 ± 3.5	46.3 ± 7.4
CN2	22.7 ± 0.1	24.4 ± 6.8	26.6 ± 3.6	29.1 ± 5.0	34.0 ± 2.3	39.0 ± 3.0
RCN	24.3 ± 0.9	27.2 ± 1.4	19.9 ± 2.5	27.3 ± 2.1	29.5 ± 2.5	31.9 ± 3.2
WCS	48.9 ± 19.9	51.7 ± 12.5	52.5 ± 15.0	43.9 ± 8.1	66.0 ± 16.0	53.7 ± 1.6
MB	39.6 ± 5.7	43.3 ± 2.0	48.0 ± 1.8	52.9 ± 0.5	56.7 ± 1.5	59.6 ± 1.4
WB	36.2 ± 1.2	51.7 ± 7.0	60.0 ± 7.1	81.2 ± 3.3	91.8 ± 2.5	93.7 ± 2.7
SBM	14.5 ± 0.3	18.1 ± 2.6	31.9 ± 22.6	48.6 ± 24.1	46.0 ± 19.8	63.2 ± 21.2
Roughages						
CS1	70.9 ± 5.7	73.1 ± 2.1	71.5 ± 3.3	69.1 ± 1.1	73.6 ± 7.5	73.4 ± 1.1
CS2	74.3 ± 0.3	72.7 ± 2.9	73.9 ± 0.5	74.5 ± 0.3	73.5 ± 2.6	76.1 ± 5.2
SC	36.2 ± 0.6	35.2 ± 0.8	36.2 ± 1.0	38.2 ± 1.5	42.4 ± 1.8	55.0 ± 2.8
AH	52.8 ± 24.6	58.7 ± 21.2	42.8 ± 1.1	66.4 ± 16.2	69.8 ± 16.6	80.5 ± 10.6
AC	38.2 ± 0.3	41.8 ± 5.2	41.2 ± 4.7	45.3 ± 9.4	53.5 ± 5.6	66.8 ± 1.5
PG	29.2 ± 2.2	27.9 ± 2.1	28.7 ± 2.1	27.2 ± 2.3	30.5 ± 1.8	36.2 ± 3.2
PGH	24.7 ± 0.1	10.7 ± 1.7	19.7 ± 2.3	16.8 ± 2.2	17.5 ± 1.0	19.1 ± 2.9
NP	36.5 ± 11.8	27.0 ± 0.7	27.4 ± 1.4	27.0 ± 1.3	29.1 ± 1.3	38.5 ± 0.8
BH	40.6 ± 3.0	40.6 ± 1.4	41.9 ± 0.6	42.6 ± 1.3	44.0 ± 1.0	49.6 ± 2.1
PNH	37.6 ± 4.4	40.7 ± 1.3	42.0 ± 2.6	43.0 ± 7.5	54.4 ± 1.0	66.4 ± 3.6
By-Products						
SP	67.7 ± 0.2	77.8 ± 5.2	79.8 ± 2.4	79.4 ± 4.0	79.2 ± 1.2	84.9 ± 7.1
BCP	35.8 ± 18.2	44.2 ± 21.2	46.3 ± 22.7	48.7 ± 25.5	48.3 ± 21.2	54.7 ± 19.6
BG	18.4 ± 0.5	24.8 ± 1.4	28.8 ± 3.1	33.2 ± 3.2	39.3 ± 3.3	51.4 ± 7.9
DG	39.1 ± 1.5	48.4 ± 2.5	50.2 ± 3.1	53.0 ± 2.7	55.1 ± 3.1	62.5 ± 4.3
BTS	18.6 ± 1.7	12.6 ± 8.2	25.0 ± 9.3	23.0 ± 3.1	26.5 ± 6.3	24.0 ± 5.3

[a] Mean ± SD ($n = 4$). [b] The abbreviation of feedstuffs are as described in Table 2.

samples fit in the model. This irregularity may be due to the contamination of the residue with microbial protein also influx of other nitrogenous material into the bag (Kennedy et al., 1984; Nocek and Grant, 1986). Theoretically, the initial disappearance of protein is close to the portion of water soluble and mechanical particle loss at 0 period (Nocek and Grant, 1986), and therefore it is the minimum point in the incubation curve. The amount of protein disappearance increased as incubation time before reaching the peak. Protein disappearances of different feedstuffs were deviated from the curves. It was either too low at 4th incubation hours of AH (alfalfa hay) sample or too high in the sample of EWSB (extruded whole soybean) at 0 h and the sample of FM (fish meal) at 2 h.

Table 4
The nonlinear estimates and the effective degradability of crude protein in the ruminal incubated feedstuffs in trial 1

Feedstuffs	Effective degradability							
	Nonlinear estimates [a]			outflow rates [b], $\%h^{-1}$			NRC	
	a	b	c	2	5	8		
Corn gluten meal	6.2	8.7	2.1	10.7	8.8	8.0	45	
Feather meal	22.1	10.2	18.1	31.3	30.1	29.2	29	* [c]
Soya pomace	67.7	12.5	84.7	79.9	79.5	79.1	–	
Brewers grain	19.6	47.4	4.7	52.9	42.6	37.1	47	
Distillers grain	42.7	21.7	8.6	60.3	56.4	53.9	53	*
Meat and bone meal	37.9	21.7	14.4	57.0	54.0	51.9	51	*
Wheat bran	37.1	60.3	15.4	90.5	82.6	76.8	71	*
Corn 1	27.2	29.5	4.3	47.3	40.8	37.5	48	
Corn 2	22.3	25.4	4.6	40.0	34.5	31.6	48	

[a] a = The portion (percentage) of crude protein solubilized at initiation of incubation; b = the fraction (percentage) of crude protein potentially degradable in the rumen; and c = the constant rate (percentage per h) of disappearance b. [b] EDCP calculated for $k = 2$, 5 or 8 ($\%\ h^{-1}$) solid outflow rates. [c] * represents results agree with the NRC.

The procedure of ruminal incubation in trial 1 encountered some phenomena that could be modified to improve data accuracy. First, the mixing and blending between nylon bags and rumen contents might be limited by the spaces among the bags inside the tube. Secondly, the large volumes of the poriferous tube cause difficulty in insertion and withdrawal from rumen for incubation. This may also cause ruminal injury. Thirdly, the gas formation of the feedstuff fermentation caused bloating within nylon bags that might interfere the flowability of ruminal fluid and fermentation products. Fourthly, the small sample size of 1 g easily caused error in incubation and analysis. To eliminate the mentioned problems, the incubation procedure was modified in the second trial for more precise results.

3.2. Evaluation of protein degradability in trial 2

The crude protein disappearance rates of the forage, by-products and the concentrates are presented in Table 5. Most of the feedstuffs (11 out of 13) were fitted into the model of Orskov and McDonald (1979) or their modified model. The protein disappearances of fish meal, soybean meal and beancurd pomace possess a log period in their curve. The log period could not fit in the model of Orskov and McDonald (1979). Therefore the modified model of Orskov et al. (1981) was applied in the second trial. Only the data of the Bermuda hay (BH) and corn No. 1 fitted in neither model and this may be due to the experimental error. Evaluations of the protein degradabilities of Bermuda hay and corn No. 1 therefore were not obtained.

Values (a, b, c) of the model in different feedstuffs are presented in Table 6. These include pangola hay (PH), soya pomace, corn silage 1 (CS1), rice bran, napier grass (NP), distillers grain, brewers grain, alfalfa hay, fish meal, soybean meal and beancurd

Table 5
The percentage of crude protein disappearance from ruminal incubated feedstuffs in fistulated dairy cattle in trial 2

Feedstuffs	Incubation time, h						
	0	4	8	12	24	48	72
Roughages							
AH [b]	40.6	51.5±4.3 [a]	78.9±3.6	81.7±4.9	92.8±0.3	91.8±2.8	94.1±0.3
BH	47.5±2.3	43.5±0.2	43.9±0.9	47.3±0.4	51.3	61.5±2.2	67.2±2.0
NP	26.4±1.5	25.4±0.5	27.6±2.5	36.3±1.2	48.6±6.3	63.9±2.2	69.3±4.1
PH	32.1±3.1	31.0±3.1	31.9±3.8	40.0±2.0	63.4±2.2	61.0±1.7	70.5±1.4
CS1	73.5±0.1	71.9±1.4	74.5±1.9	73.7±4.0	81.6±1.2	86.1±0.8	85.5±3.0
By-products and concentrates							
BCP	24.6±0.2	24.7±1.1	24.8±0.7	26.6±3.0	44.0±3.0	78.8±1.2	
BG	24.5±3.2	31.3±6.8	35.8±3.8	51.4±5.1	68.1±11.1	77.8±1.5	89.3±3.0
CN1	32.6±1.9	36.6±0.8	39.4±3.6	43.0±2.5	47.2±1.5	65.5±5.9	92.2±1.5
DG	41.4±1.0	50.3±2.0	50.9±2.1	58.8±3.6	63.8±4.0	69.9±3.2	82.9±1.6
FM	33.1±0.3	34.4±1.8	33.0±0.8	36.1±1.1	37.2±3.6	44.0±2.1	59.3±4.4
RB	28.8±1.2	39.7±2.4	40.3±2.6	50.0±4.4	56.1±4.9	63.4±3.9	79.2±2.0
SBM	9.9±0.5	11.2±2.8	18.1±4.7	42.6±5.6	61.8±1.6	91.3±7.2	
SP	49.0±1.8	74.7±5.1	78.5±1.6	82.5±4.0	87.5±1.9	95.0±0.2	96.2±0.5

[a,b] The footnotes are the same as in Table 3.

pomace. The calculated crude protein effective degradabilities (EDCP) of incubated ruminal feedstuffs are presented in Table 6.

Most of the crude protein disappearance of feedstuffs from ruminal incubated nylon bags fit into the model of Orskov and McDonald (1979) in this trial. From the protein disappearance at different incubation times in Table 5, it showed a trend of more precise curve than the data derived from first trial.

Table 6
The nonlinear estimates and the effective degradability of crude protein in the ruminal incubated forages in trial 2

Feedstuffs	Effective degradability							
	Nonlinear estimates [a]			outflow rates [b], $\%h^{-1}$			NRC	
	a	b	c	2	5	8		
Pangola hay	27.5	56.6	2.0	55.5	43.5	38.6	–	
Soya pomace	55.0	38.3	22.7	90.2	86.4	83.3	–	
Corn silage	70.5	18.0	3.2	81.6	77.5	75.6	69	* [c]
Rice bran	32.6	49.0	5.0	67.7	57.2	52.5	–	
Napier grass	20.9	60.8	2.4	53.8	40.4	34.7	–	
Distillers grain	44.5	40.4	5.0	73.4	64.7	60.1	53	*
Brewers grain	21.4	69.8	7.4	76.3	63.0	54.9	51	*
Alfalfa hay	31.4	62.7	14.4	86.5	78.0	71.8	72	*
Fish meal	32.8	15.3	3.6	42.6	38.5	37.5	40	*
Soybean meal	20.3	77.3	12.9	87.2	76.0	68.0	65	*
Beancurd pomace	24.9	71.0	8.6	82.5	69.8	61.7	–	

[a,b,c] Footnotes are the same as in Table 4.

Comparison of the feedstuffs crude protein disappearances from different sizes of nylon bag that incubated in the rumen (Tables 3 and 5), it appeared that both trials derived the same trend of the protein disappearance curves, with some exception for variation in trial 1. When compared the influence of the size of bags to the result, it showed a higher protein disappearance curves in the big one than the small one (Table 3 and 5). This result agreed with the data of DeBoer et al. (1987) that the crude protein disappearance rate of large incubation bag was higher than the smaller bag. When comparing the standard deviation of the means of the crude protein disappearance rate, the smaller incubation bags in trial 1 showed higher standard deviation than that derived from trial 2. Most of the data derived from trial 2 fit in the models as compared with only one third of the data from the first trial. Therefore, the size of the incubation bags was recommended as 10×20 cm instead of 4.5×6.5 cm. The modified in situ method were recommended.

In comparing the figures derived from the trials and the data of NRC (1988), crude protein degradabilities of the feedstuffs analyzed were listed in Tables 4 and 6. The protein degradabilities of the feedstuffs, that are star marked in the tables, showed the results were agreeing well with each other. The result constants of soybean meal for example, were quite agreeing with Ganesh and Grieve (1990) who derived value of 21.28 and 78.72 for a and b value respectively whereas our values for the value were 20.3 and 77.3 respectively. This result can further confirm that the procedure and precision of the trial are acceptable for the practical application, although differences in the analysis results among laboratories still exist.

Most of the evaluated feedstuffs were locally produced. Data were rarely available from the literature except those conventional feedstuffs. Although the extraction with water as conducted in this trial is not a good estimate of the solubilization of protein in the rumen as showed by Wohlt et al. (1973) and Crooker et al. (1978), this estimate is adequate for fermented forages and feeds with the soluble protein being mostly NPN. Proteins in feeds such as wheat, soy and oats are better extracted with weak buffer. Therefore the derived a value can only represent soluble protein in feedstuffs with source of protein mostly in NPN. This information can still provide a way for comparison among laboratories. Take corn silage for example, the value of constant a was quite large whereas the value of constant b was very small. This may be due to a large portion of water soluble protein in corn silage (Table 6), since silage protein contained large percentage of NPN. Janicki and Stallings (1988) and Arieli et al. (1989) found the same results. The protein degradabilities of pangola and napier hay were 35–39%. Their values of the a and b were quite similar between these forages. In contrast to the pattern of pangola and napier hay, the crude protein disappearance curve of fish meal showed a large a value with small b value. This may suggest a slower and a stabler degradation processes in rumen, although water soluble fraction may not represent to soluble protein in this kind of feedstuffs.

The beancurd pomace is a by-product commonly used in dairy feed in Taiwan. It is the residue from the processing of beancurd or soymilk: a by-product after filtrate water soluble fraction from cooked soybean flour. It contained approximately crude protein 21%, crude fat 10%, crude fiber 14%, NFE 45%, and ash 3%, on air dry basis. The soya pomace is a dried by-product of soy sauce industry, and possesses a protein character

similar to corn silage that was rapidly degraded in rumen. It may be because both feedstuffs were fermentation byproducts. Soy sauce is a soluble fraction of the extract of a liquid media in a year long incubation of cooked defatted soybean with *Aspergillus oryzae*. The soya pomace contained approximately 25% crude protein, 10% crude fat, 16% crude fiber, and 1.4% sodium (air-dry basis) depending on the manufacturing procedure.

The sample of beancurd pomace showed a lag period in the first 8 h of ruminal incubation. Its disappearance curve after 8 h incubation was similar to soybean meal as showed by Stern et al. (1985). Both brewers grain and distillers grains are major source of dairy feedstuffs too. Their crude protein contents, on a dry matter basis, were 28.6 and 17.0%, respectively. The protein degradabilities were 55–60% under an 8% ruminal outflow rate (EDCP, Table 6). It showed a higher value compared with the result of Stern and Satter (1984) that obtained a 45% degradabilities in two distillers grains. It also showed a higher value than NRC (1988). Rice bran that is also a major by-product conventionally used in nonruminant feeds, possesses a 53% protein degradability and is a potential source of protein for dairy cattle.

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