EFFECTS OF RATIO OF CONCENTRATE TO ROUGHAGE AND KINDS OF HAY IN A RATION ON ESTIMATING THE RUMEN DEGRADABILITY OF PROTEIN OF FORMULATED CONCENTRATE

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Summary

Formula feed for fattening cattle ground through 2 mm screen was incubated in the rumen of sheep and goats to evaluate effects of ratio of concentrate to hay and kinds of hay in a ration on determining the degradability (dg) value of protein using *in sacco* technique. Following results were obtained: 1) Residual dry matter (DM) and crude protein (CP) of formula feed decreased as the time of incubation increased. Regression analyses showed that rates of degradation of DM and CP in the rumen were not the same when they were determined under feeding of rations with different percentages of concentrate. 2) Rate of passage of digesta from the rumen differed between feeding of Italian ryegrass hay ration and that of alfalfa hay ration, but was not influenced by the percentage of concentrate in a ration. 3) The dg value was different when it was estimated with results obtained from determinations under feeding of Italian ryegrass hay ration or that of alfalfa hay ration. The percentage of concentrate in a ration had no influence on the dg value of protein in formula feed.
(Key Words: Protein Degradability, Formulated Feed, Italian Ryegrass, Alfalfa Concentrate Ratio)

Introduction

A new system of evaluation for nitrogen requirement of ruminants has been introduced by British Agricultural Research Council in 1980. The system based on the newly developed index expressed as the rumen degradability of dietary protein (dg). Since then, many workers have devoted for estimating the dg value of dietary protein of various feeds (Okubo et al., 1986). Determinations for dg values of dietary protein have conveniently carried out by *in sacco* technique in conjunction with the estimation of passage rate of digesta through the rumen (ϕrskov and McDonald, 1979, Okubo et al., 1986). Sekine et al. (1986) failed to show a clear evidence that the dg value of protein in a formulated feed was able to be determined by calculation using the composition of ingredients of a formula feed and the dg value of each ingredient determined individually. They have suggested that the dg value is influenced by the rumen fermentation. Compositions of ruminal volatile fatty acids, and density and composition of microflora have changed as percentage of concentrate in a ration increased from 50 to 90% in fattening cattle (Hishikawa et al., 1988).

The present study was to evaluate effects of ratio of concentrate to hay and kinds of hay in a ration on determining the dg value of protein of formula feed.

Materials and Methods

Animals used were 2 Suffolk × Corriedale rams and 2 Saanen castrated male goats fitted with rumen cannulae. They were fed rations consisting of commercial formula feed for fattening beef as concentrate and Italian ryegrass 2nd cut hay chopped in 5 cm length (ryegrass ration) and cubed alfalfa hay (alfalfa ration) at maintenance level. Rations were provided by mixing concentrate and hay with ratios of 0 : 100 (R0 for ryegrass ration or A0 for alfalfa ration), 30 : 70 (R30 or A30), 60 : 40 (R60 or A60)

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and 85 : 15 (R85 or A85) on air dry-matter basis.

Proximate compositions of formula feed and hays were shown in table 1. The experimental period for each dietary treatment totaled 21 days consisting of 7-day preliminary period and 14-day comparison period. Digestion trial was conducted in the comparison period using total collection method. Urine was also totally collected in the same period. Twenty grams of the chromium mordant cell wall constituents (Cr-CWC, Uden et al., 1980) were administered through the rumen cannula at morning feeding (8 : 30 a.m.) on the first day of the comparison period to determine the rate of ruminal passage of digesta. After the

TABLE 1. PROXIMATE COMPOSTION OF FEEDS USED IN THE EXPERIMENT

	DM	OM	CP	CC[1]	NDF	ADF	ADL
	as is %	% DM					
Italian ryegrass hay	87.6	80.9	12.8	38.9	61.1	39.2	4.5
Cubed alfalfa hay	85.9	90.2	21.5	63.6	36.4	30.1	6.3
Formula feed	89.0	94.7	14.4	86.4	13.6	5.9	1.4

[1] Cellular contents.

administration of Cr-CWC, feces were collected at 4-hour intervals for 5 days. Aliquot samples were stored at −20℃ for further analyses. The concentration of Cr in feces was determined by the method described by Yoshida et al. (1967). The passage rate constant (kp) was calculated by the method presented by Grovum and Williams (1973). The determination of the rates of degradation of crude protein started on the 6th day of the comparison period using *in sacco* technique reported by ϕrskov and McDonald (1979). The nylon bag used was made with 300 mesh nylon fabrics (pore size 45 μm) and was 5 × 10 cm in size. The bag contained 2 g of a feed sample ground through a 2 mm screen and 2 steel balls weighing about 11 g as a weight. Samples were the same hay and formula feed used for feeding but separately prepared in different bags for ruminal incubation. Duplicated bags were incubated in the rumen for 3, 6, 12, 24, 48 and 72 hours. After the incubation, bags withdrawn from the rumen were vigorously washed with tap water to eliminate the ruminal digesta on their surface and then in running water until wash-out water had become clear. The residues in the bag were dried in a forced-air oven at 55℃ and dried to the constant weight at 105℃ for the determination of dry matter (DM) in the residues.

Degradation of protein in the rumen was calculated by the equation presented by ϕrskov and McDonald (1979) using non-linear iterative least square method described by Mertens and Loften (1980). The equation used was as follows:

$$P(t) = RD + SD\,(1 - e^{-kd \cdot t}),$$

where P (t) = protein degraded at a given time (t), RD = rapidly degraded fraction of protein, SD = slowly degraded fraction of protein and kd = degradation rate constant. The effective degradability (dg) of protein in the rumen was calculated by the following equation presented by ϕrskov and McDonald (1979):

$$\text{Effective dg} = RD + SD \cdot kd/(kd + kp).$$

Then, reduction rate of crude protein in the bag during the incubation was calculated by fitting results to the following equation: $y = a + b \cdot \ln(x)$, assuming that protein in the formula feed were totally digestible when it stayed in the rumen for infinite time. Statistical analyses were carried out by the method described by Steel and Torrie (1960).

Results

Table 2 shows mean digestibilities for nutrients of rations given to animals. Digestibility of DM increased as the ratio of concentrate increased in a ration. Digestibility of CP also increased as the ratio increased as the ratio increased, but the degree of its increment was smaller than that of DM. Digestibilities of fiber fractions in the ryegrass ration decreased as the ratio of concentrate in ration increased, but tended to in-

TABLE 2. MEAN DIGESTIBILITIES OF NUTRIENTS OF RATIONS GIVEN TO ANIMALS

	RO	R30	R60	R85	AO	A30	A60	A85
	%							
DM	50.3	58.0	66.4	77.4	65.9	71.2	80.9	85.3
CP	66.1	64.7	69.2	71.7	79.9	81.5	83.5	83.9
NDF	49.7	42.9	35.3	34.1	52.2	48.2	53.2	60.0
ADF	42.2	36.1	34.2	30.7	57.3	51.9	59.0	62.9

crease in alfalfa ration.

Residual DM in the bag decreased as the incubation time increased. Patterns of DM degradation of formula feed appeared to differ when it was determined in rations consisting of different ratios of concentrate to hay and of grass hay or legume hay as shown in figure 1. Regression equations of residual DM (RDM, g/100 g of initial weight) on incubation time (T, hour) were calculated for determinations under each ration treatment as follows:

RO ration; $r = -0.982$, RDM = 77.8 − 16.4(±1.5) ln(T), s.e. ± 1.87, $p < 0.01$,

R30 ration; $r = -0.991$, RDM = 62.3 − 11.5(±0.7) ln(T), s.e. ± 0.85, $p < 0.01$,

R60 ration; $r = -0.990$, RDM = 55.0 − 11.1(+0.7) ln(T), s.e. + 0.87, $p < 0.01$,

R85 ration; $r = -0.973$, RDM = 58.0 11.3(±1.3) ln(T), s.e. ± 1.49, $p < 0.01$,

AO ration; $r = -0.975$, RDM = 57.1 − 13.1(±1.5) ln(T), s.e. ± 1.67, $p < 0.01$,

A30 ration; $r = -0.992$, RDM = 50.0 − 11.0(±0.7) ln(T), s.e. ± 0.80, $p < 0.01$,

A60 ration; $r = -0.981$, RDM = 42.2 − 7.3(±0.7) ln(T), s.e. ± 0.79, $p < 0.01$,

A85 ration; $r = -0.985$, RDM = 46.9 − 9.7(+0.8) ln(T), s.e. ± 0.93, $p < 0.01$.

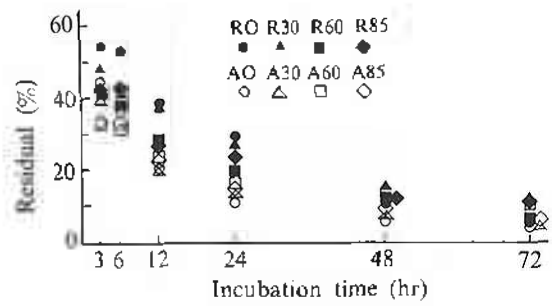

Figure 1. Changes with incubation time in residual dry matter in the bag incubated in the rumen when animals were given rations with diverse percentage of concentrate.

The homogeneity of coefficients of regression was tested among rations to decide whether rates of DM degradation were considered to be the same when they were determined under different feeding conditions. The determination under RO ration feeding was significantly greater than those of R30, R60, R85, A30, A60 and A85, while that under A60 was significantly lower than those of RO, R30, R60, R85, AO and A30 ($p < 0.05$). Rates of DM degradation determined under other feeding conditions showed no statistically significant difference.

Residual CP of formula feed in the bag decreased as the time of incubation increased as shown in figure 2. Residual CP (RCP, g/100 g of initial CP) in the bag regressed on incubation time (T, hour) for determinations under different feeding regimes and following regression equations were obtained:

RO ration; $r = 0.990$, RCP = 72.1 − 14.6(±1.0) ln(T), s.e. ± 1.14, $p < 0.01$,

R30 ration; $r = -0.961$, RCP = 68.9 − 12.2(±1.7) ln(T), s.e. ± 1.96, $p < 0.01$,

R60 ration; $r = -0.996$, RCP = 70.4 − 15.4(+0.7) ln(T), s.e. ± 0.79, $p < 0.01$,

R85 ration; $r = -0.969$, RCP = 79.0 − 17.1(±2.1) ln(T), s.e. ± 2.42, $p < 0.01$,

AO ration; $r = -0.973$, RCP = 67.9 − 15.8(±1.8) ln(T), s.e. ± 2.09, $p < 0.01$,

A30 ration; $r = -0.997$, RCP = 62.6 − 13.3(±0.4) ln(T), s.e. ± 0.55, $p < 0.01$,

A60 ration; $r = -0.976$, RCP = 53.9 − 11.1(±1.2) ln(T), s.e. ± 1.38, $p < 0.01$,

A85 ration; $r = -0.971$, RCP = 51.3 − 11.6(±1.4) ln(T), s.e. ± 1.58, $p < 0.01$.

The homogeneity of coefficients of regression was tested among rations to decide whether rates of CP degradation were considered to be the

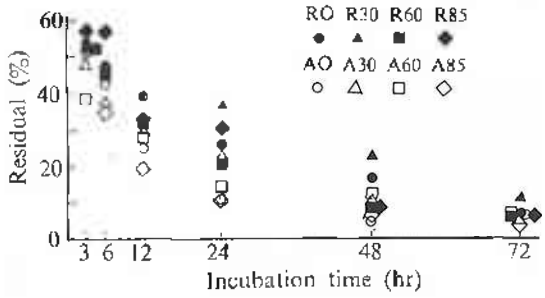

Figure 2. Changes with incubation time in residual crude protein in the bag incubated in the rumen when animals were given rations with diverse percentage of concentrate.

same when they were determined under diverse feeding regimes used in the present study. The determination under R60 feeding was significantly greater than those determined under feeding of A30, A60 and A85 ($p < 0.05$). That under R85 feeding was also greater than that of A60 ($p < 0.05$). The determination under alfalfa ration feeding appeared to be greater in AO ration, but no significant differences were found among regimes of alfalfa ration feeding.

Mean rates of passage of digesta through the rumen (kp, hr^{-1}) were shown in table 3. In feeding of ryegrass ration, kp showed almost the same irrespective of the ratio of concentrate to hay except for the ration without concentrate which tended to be lower than the others. In feeding of alfalfa ration, kp tended to decrease as the ratio of concentrate in a ration increased. There was a significant difference in kp between RO and AO rations, while no significant difference was observed between ryegrass and alfalfa rations with diverse ratios of concentrate to hay.

Using results obtained in the present study, effective dg values were calculated for CP of formula feed as shown in table 4. When the dg was calculated by the values determined under feeding of ryegrass or alfalfa ration, it showed a fairly constant value with some variations. Thus, dg values for each ration were pooled and averaged. The pooled dg calculated using results obtained from the ryegrass ration was significantly lower than that calculated using results obtained from the alfalfa ration ($p < 0.05$).

Discussion

Patterns of DM degradation of formula feed differed significantly when they were determined under feeding of rations with different ratios of

TABLE 3. MEAN RATE OF PASSAGE OF DIGESTA FROM THE RUMEN FOR RATIONS

	% of formula feed in ration			
	0	30	60	85
	hr^{-1}			
Ryegrass ration	0.025	0.034	0.032	0.034
Alfalfa ration	0.037	0.031	0.026	0.022
Statistical significance	$p < 0.05$	ns[1]	ns	ns

[1] Not significant

TABLE 4. EFFECTIVE DG VALUES ESTIMATED UNDER FEEDING OF RATIONS CONTAINED DIVERSE PERCENTAGES OF CONCENTRATE

Determined	% of formula feed in ration				
under feeding of	0	30	60	85	Pooled
	%				
Ryegrass ration	73	64	74	62	68 ± 6
Alfalfa ration	77	77	81	86	80 ± 4
Statistical significance					$p < 0.05$

concentrate to hay. Those of CP degradation of formula feed also different among feeding of diverse rations. Density of free-living bacteria in the rumen decreased from about 1.5×10^{10}/ml of rumen fluid to 0.5×10^{10}/ml, when percentage of concentrate increased from 50 to 90% in cattle (Hishikawa et al., 1988). The composition of ruminal bacteria groups also changed as percentage of concentrate increased in a ration (Hishikawa et al., 1988). Protozoa found in cattle given the ration containing 60% of concentrate were 25 species in 11 genera and decreased 8 species in 2 genera when percentage of concentrate increased to 90% in a fattening ration (Kariya et al., 1988). The composition of ruminal volatile fatty acids has been associated with changes in rumen microflora and fauna (Hishikawa et al., 1988, Kariya et al., 1988). Therefore, difference found in degradation patterns of DM and CP in present study is inferred to be responsible for changes in ruminal fermentation caused by the shift of density and/or composition of rumen microflora and fauna.

The kp for RO ration was significantly lower than that of AO ration. Digestibility of DM for RO ration was lower than that of AO ration (table 2). Thus, it may be responsible to the slower rate of passage of digesta from the rumen under feeding of RO ration. Addition of concentrate in a ration, however, showed no significant difference in kp's for ryegrass and alfalfa rations. Thus, concentrate mixed in a ration more than 30% appears to have no influence on a passage rate of the ruminal digesta.

The different effective dg values were obtained from the results determined under feeding of ryegrass and alfalfa rations, while diverse ratios of concentrate to hay appeared to have no effect on the dg value of CP of formula feed. Thus, determinations of dg value may be influenced by the feeding with grass hay or legume hay. Sekine et al. (1986) failed to show a clear evidence for estimation of the dg value of protein in a formulated feed by an additive fashion with using the composition of ingredients and the dg values of protein for individual ingredients, when rumen degradation of protein was determined by 2- to 3-mo.-old calves and 14-mo.-old steers. They have suggested that the dg of protein was partially influenced by the ruminal fermentation.

From the discussion above, it is concluded that the dg value of formula feed is influenced by the kind hay used for the determination of the degradation of protein in the rumen and the passage rate of digesta from the rumen. The percent of concentrate in a ration appears to have no influence on the determination of the dg value of protein of the corresponding concentrate given to animals to be used in determination of ruminal degradation of protein and passage rate. It is also suggested that the study on standardization of methods for determining the dg values of feedstuffs is required to facilitate the use of the dg value as an index for the evaluation of nutritive value of protein for ruminants.

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