Evaluation of Nutritive Value of Forages by Golden Hamster

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As the nutritional evaluation of herbages by the use of large animals can not easily be made, because it requires large amount of samples, labor, time, and cost, the use of small experimental animals has been deviced. If an experimental herbivora, smaller than guinea pig or rabbit, could be found out, it would be possible to evaluate large number of forages by using much smaller amount of samples, through responses of the animal in growth, reproduction and lactation etc. Such experimental herbivora might also be useful in clarifying metabolism of forage components in animal. The author attempted to use golden hamster (*Mesocricetus auratus*) for that purpose and has proved its usefulness by feeding experiments. Results so far obtained will be presented briefly.

Life cycle of hamster, and structure and function of its digestive organ

The hamster, which is known to be used as an experimental animal in relatively recent years, is a small animal with body weight of about 150 g, gestation period of 16–17 days, average litter size of about 10, and resistance to diseases. Raising management and planned reproduction can be done quite easily. The hamsters in the author's laboratory were originated from a pair of male and female, followed by repeated inbreeding for more than 20 generations, so that they are of extremely high genetic homogeneity.

A characteristic of hamster as an experimental herbivora is found in structure and function of its stomach. The stomach consists of two parts, pregastric pouch and gastric pouch, and volatile fatty acids (VFA) are produced in it. Protozoa in pregastric pouch and caecum are Trichomonas-like flagellate with a body size of 10.9–6.4 μm×7.9–4.4 μm. The number of protozoa is 10^6–10^8 per g of ingesta, although it varys with kinds of feeds and more protozoa inhabit in the caecum than in the pregastric pouch. The hamster, having such a digestive system, utilizes urea in protein metabolism[1], and requires less amino-acids[2], like ruminants. The significance of the presence of bacteria in nitrogen metabolism is clearly shown by comparing the incorporation of ^{15}N into bacteria during the *in vitro* fermentation of ^{15}N-labelled sorghum with ingesta of bovine rumen, hamster pregastric pouch and hamster caecum (Fig. 1).

Roughage utilization characteristics of hamster

1) Forage supply and growth of hamster

Feeding experiments using refined diets showed that hamsters grow normally at a level of cellulose content in diets up to 50%. In case of leguminous forages, growth and even reproduction are possible with a supply of fresh legumes alone.

2) Roughage digestibility of hamster as compared to sheep

Digestibility of 5 kinds of alfalfa hay differing in nutritive value was compared between hamster and sheep. A high positive correlation was found in the digestibility between both animals (Fig. 2-a). In this case, significant correlations were also found between the

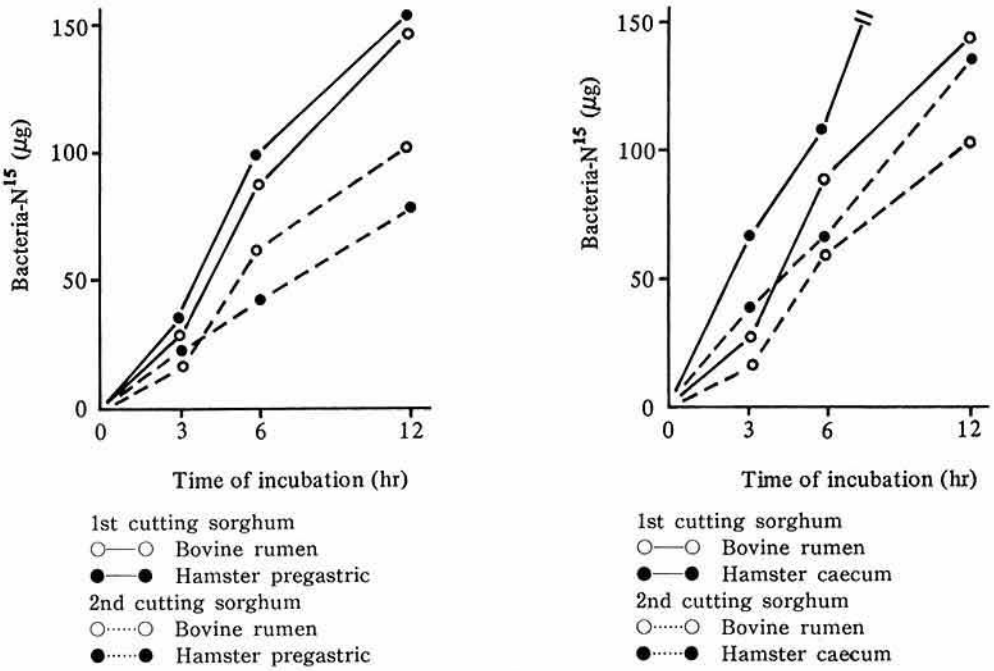

Fig. 1. Comparison of incorporation of ^{15}N-nitrogen into microorganisms during *in vitro* fermentation of ^{15}N-labelled sorghum with ingesta of bovine rumen, hamster pregastric and hamster caecum

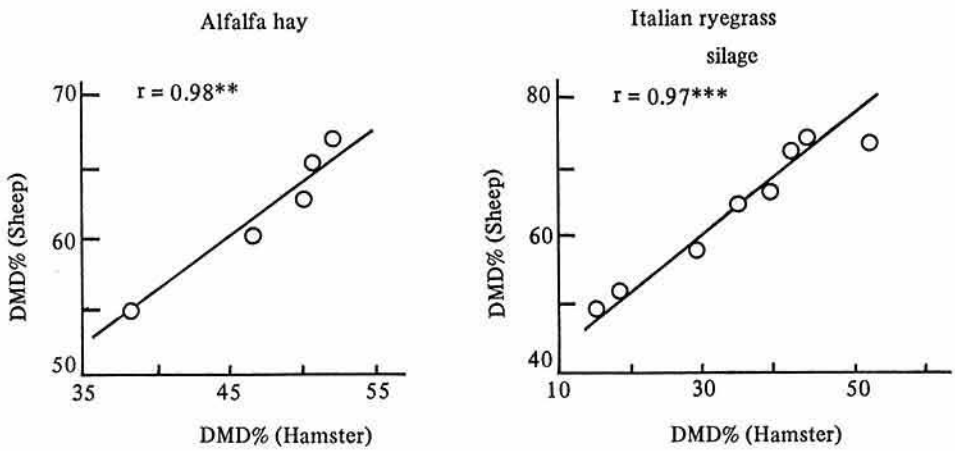

Fig. 2. Relation between dry matter digestibilities (DMD) by sheep and hamster in feeding fed with forage diets

body weight gain of hamster and the digestibilities of dry matter (DM) and cell wall constituents (CWC) as well as nitrogen absorption rate of the sheep, indicating clearly that the nutritive value of alfalfa can be evaluated by the weight gain of hamster. Furthermore, in a comparative experiment using 8 kinds of Italian ryegrass silage differing in growth stage at harvest and cutting time of the grass, a high correlation of r= 0.968 was found between DM digestibility of hamster and that of sheep (Fig. 2-b). Also,

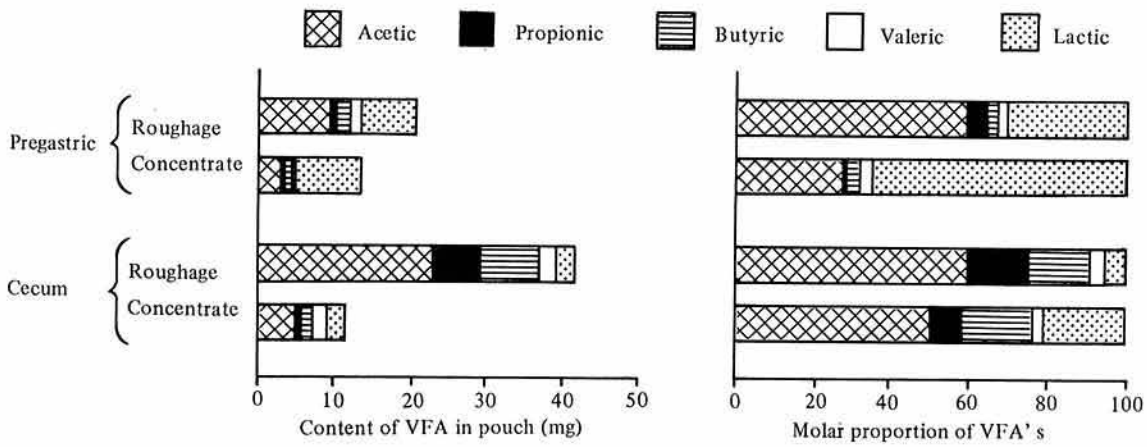

Fig. 3. Comparison of constitutions of volatile fatty acid (VFA) of ingesta of pregastric pouch and caecum between hamsters fed with concentrate and fed with roughage

a high positive correlation was recognized in feed intake between hamster and dairy cattle. All these results show that general quality of roughages can be evaluated by the use of hamster.

3) Changes in structure and function of hamster's digestive organ caused by roughage feeding

When hamster were fed with a roughage diet, weight of the whole alimentary canal was increased 2 to 3 times with an increased length of intestine as compared to those of the hamsters fed with concentrate. Amount of VFA in pregastric pouch and caecum was also increased 2 to 3 times by the roughage feeding. In the pregastric pouch the proportion of acetic acid was high when fed with roughage, while the proportion of lactic acid became high when fed with concentrate. In the caecum, however, the proportion of acetic acid in the organic fatty acids was high in both groups (Fig. 3). Furthermore, enzyme activities related to $NADP^+$ formation in the liver and epididymal adipose tissue were measured with a result that the malic enzyme activity was reduced in hamster fed with roughage. These results show that the digestive system of hamster changes to the herbivorous type by roughage feeding.

Evaluation of roughages

1) Method of supplying roughage

The following method was proved to be best for feeding hamsters: feeds with high moisture content such as fresh forage or silage are ground by meat-chopper, while dry feeds like hay or hay cubes are crushed, then casted to form pellets, and crushed again. Raising cages and feeders for hamster have also been devised.

2) Age to start herbage feeding, and pre-feeding

To determine the right age (in day) of hamster for starting the herbage feeding experiment, and to know the suitable diet for pre-feeding, a period of 40 days from the weaning stage (25 days of age) to the maturation (65 days of age) was divided into 4 periods, and alfalfa pellets were supplied at each period. Feed intake, body weight gain, digestibility, weight of alimentary canal, number of protozoa, and serum components were examined. Results showed that a rapid response to herbage feeding occurs by the age of 55 days. The extent of the response varied with the kinds of pre-feeding diet, showing more rapid response of hamsters which had been fed with roughage than that fed with concentrate.

Examples of nutritive value evaluation

1) Soil fertility and nutritive value of forages

The first and second cuttings of forage sorghum grown on fertile or less fertile soils were applied to hamsters, and their growth and digestibility were examined. Although there was no difference in digestibility of DM and CWC as well as in nitrogen absorption between fertile and less fertile soils, the body weight gain in feeding with the first cutting was greater with sorghum grown in fertile soil than that of less fertile soil, and the efficiency of feed utilization was extremely high (Table 1). It was presumed that minerals might be responsible for the difference in weight gain, but no difference was found in Na, K, Ca, and Mg concentrations in serum between two plots. Thus, the reason why the sorghum grown on fertile soil gave a greater body weight gain is not made clear, but it is suggested that the hamster is useful in analyzing substances related to palatability and growth in feed.

2) Quality and feeding value of fermented silage

To make clear the relationship between quality of fermented silage and feeding value, different silages were prepared by using forages of different kinds, different cuttings, and of different stages with varying moisture contents and different preservatives at various temperatures for preparation and storage. A feeding experiment of hamster was carried out using these silages. Quality of fermented silages varied depending on the moisture content and water soluble carbohydrate (WSC) content of materials and on storage temperatures. The quality as expressed by pH_2, Flieg's score, volatile basic nitrogen/total nitrogen (VBN/T-N) was found to show significant relations with biological responses of the hamster such as weight gain, feed intake, and feed efficiency, etc. In case of silages of leguminous forage, it was made clear that the silages which showed greater DM intake by the hamster gave more effect on weight gain, and that the DM intake has a high negative correlation ($r=-0.960$) to VBN/T-N.

All these results indicate the great usefulness of hamster as an experimental animal to evaluate feeding value of silages.

3) Response of hamster to particular substance in herbage

Feeding value of forage is determined mostly by two factors, i.e., protein source and energy source. However, it must be taken into consideration that forages contain various particular substances which are not contained in concentrates. Estrogenic substances are one of them. In a series of experiments using hamsters, the effect of this group of substances to promote growth and feeding effi-

Table 1. Growth response of hamster fed with sorghum grown on soils with different fertilities

Cutting	Soil fertility	Intake (DM g/$BW^{0.75}$ g/day)	Weight gain (g/day)	Feed efficiency (%)	Digestibility (%)	
					Dry matter	Cell wall constituents
1st cutting	Low	0.34[a]	0.8[a]	10.9[a]	47.6[a]	25.3[a]
	Medium	0.35[a]	1.2[ab]	15.0[b]	46.3[a]	23.3[a]
	High	0.36[a]	1.4[b]	17.0[b]	45.0[a]	23.3[a]
2nd cutting	Low	0.36[a]	1.2[a]	14.3[a]	41.7[a]	12.3[a]
	Medium	0.37[a]	0.9[a]	11.1[a]	40.7[a]	12.2[a]
	High	0.38[a]	1.1[a]	12.7[a]	41.1[a]	15.1[a]

Figures with different subscripts are significantly different from each other.

Table 2. Effect of oral administration of diethylstilbestrol (DES), genistin and alfalfa extract on body weight, feed consumption and feed efficiency of young male hamsters

Treatment (per g diet)	Body weight (g)		R.C.[a]	Feed consumption (g)	Feed efficiency (%)
	Initial	Final			
Control	74.6±3.4[b]	118.8±4.0	0.72±0.09	490	9.0
DES 0.01 μg	72.2±6.2	130.2±4.3*	0.97±0.10*	537*	10.8*
Genistin 2 mg	74.0±5.3	133.0±4.1**	1.00±0.11*	540*	10.9*
Alfalfa-extract 3 mg[c]	75.6±3.2	122.3±3.9	0.74±0.08	496	9.4
Alfalfa-extract 6 mg[d]	73.9±5.7	130.9±3.5*	0.94±0.10*	535*	10.7*

a : Regression coefficient±S.D. * $P<0.05$, ** $P<0.01$
b : Results are presented as mean±S.D.
c : Equivalent to 0.33 g alfalfa meal dry matter
d : Equivalent to 0.66 g alfalfa meal dry matter

Table 3. Effect of various contents of magnesium and potassium of diet in relation to cellulose content on weight gain, feed intake and serum mineral levels in hamster

Diet No.	Mineral content (% in diet)		DM intake (g/day)	Weight gain (g/day)	Serum mineral level (mg/100 ml)			
	Mg	K			K	Na	Mg	Ca
			40% cellulose content in diet					
1	Optimum (0.05)	Optimum (0.15)	9.0[a]	0.55[a]	36.3	336	2.80[a]	15.9
2	Optimum (0.05)	High (1.84)	8.0[a]	0.53[a]	38.6	329	2.27[a]	15.0
3	Low (0.01)	Optimum (0.19)	6.1[b]	−1.18[b]	31.2	312	1.11[b]	13.5
4	Low (0.01)	High (1.65)	4.3[b]	−2.16[b]	34.4	316	1.63[b]	12.9
			2% cellulose content in diet					
1	Optimum (0.05)	Optimum (0.22)	6.3[a]	0.94[a]	31.1	314	4.29[a]	16.1
2	Optimum (0.05)	High (1.58)	5.8[ab]	1.61[a]	33.1	307	3.24[a]	15.2
3	Low (0.01)	Optimum (0.15)	5.4[b]	−0.18[b]	26.9	309	2.01[b]	15.6
4	Low (0.01)	High (1.67)	5.6[b]	0.60[b]	27.5	305	1.77[b]	14.6

Figures with different subscripts are significantly different from each other.

ciency was made clear[4-8] (Table 2), and furthermore the endocrinic mechanism of growth-promotive function of estrogenic substances has been investigated[9-11]. It is considered that the hamster is also useful as an experimental animal in detecting and evaluating particular components of forages.

4) Hypo-magnesemia of hamster

The hypo-magnesemia is known to occur in ruminant fed with Mg-deficient diets. To know the usefulness of hamster for studies in this particular field, refined diets containing cellulose at 2% and 40% with varying contents of Mg and K were prepared to feed hamsters. Biological responses and serum

mineral concentrations were measured. The hamsters fed with the diet of 40% cellulose and low Mg content showed a remarkable decrease in weight, reduced serum Mg concentration, and died with convulsive symptom (Table 3).

Future outlook of the use of hamster

If the method to evaluate roughages by using milk yield or breeding efficiency could be developed in future, the usefulness of hamster is expected to increase extremely.

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