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Comparative Digestibility in Several Artificially Fed Herbivores

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Introduction

The ecological niches provided by plant sources have encouraged the development of several adaptations in herbivores. Herbivores can be divided into three major classes: concentrate selectors, intermediate feeders and bulk and roughage eaters; these can also be further divided into several subcategories according to their feeding habits[3]. They can also be divided into pregastric fermentors and hindgut fermentors; the former being further divided into ruminants and non-ruminants[3]. These differences in feeding habit and digestive system may lead to differences in tolerance for dietary fiber and digestibility.

The present study aimed at comparing the digestibility of plant cell wall components in 8 artificially fed herbivore species.

Materials and Methods

Only one animal was available from each species: a giraffe (*Giraffa camelopardalis*), a camel (*Camelus dromedarius*), a llama (*Lama glama*), a tapir (*Tapirus indicus*) and a hippopotamus (*Hippopotamus amphibius*) kept at Maruyama Zoo, Sapporo City; and a cattle, a sheep and a horse reared at Rakuno Gakuen University. Only the cattle was in milking and in a different physiological condition from the others. The composition of the ingredients of the rations for each animal is listed in Table 1. Each animal was fed the same rations for at least 4 weeks. Daily feed intake was measured for 2 consecutive days. The amount fed and leftovers were measured and sampled for chemical analysis. Fresh fecal samples were collected at least 2 times in the two day period.

Acid detergent fiber (ADF) and acid detergent lignin (ADL) were measured according to the procedure of Goering and Van Soest[1]. Neutral detergent fiber was not measured because of the difficulty of filtration. The difference between ADF and ADL was regarded as cellulose (C)[2]. ADL is regarded as an indigestible component[4,5], and used as a natural marker for measuring digestibility. Crude protein (CP) was analyzed by the Kjeldahl method.

Results and Discussion

The composition of the rations for the animals, especially those kept in the zoo, was complicated, as shown in Table 1. Therefore, the proportion of roughage to concentrate in the rations ranged widely from 47% to 100% for the ruminants, and from 21% to 84% for the non-ruminants. The giraffe, as a ruminant, classified as a concentrate selector was fed less than 50% roughage. The hippopotamus, as a pregastric but non-ruminant fermentor, classified as a bulk and roughage eater was fed more than 80% roughage. The horse belongs to the class of bulk and roughage eaters. However, the horse used in the present study was fed about 79% concentrate in its rations.

Dry matter (DM) and ADL intake is shown in Table 2. No information on body weight for the zoo animals was available. Therefore, no accurate comparison of dry matter intake on the basis of body weight or metabolic body size was avail-

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Table 1 Composition of daily rations(kg)

	giraffe	cattle	sheep	camel	llama	hippopotamus	horse	tapir
grass hay	2.7	5.0	1.5	5.0	1.1	13.2	0.6	1.5
haycube	2.1					3.6		
zoo food	2.1			1.0	0.5			0.5
dehydrated alfalfa		2.0					0.6	0.5
beet pulp pellet		2.0						
corn silage		15.0						
alfalfa silage		15.0						
cabbage	11.0				1.8			
bean sprouts	10.8							
carrot	2.0			5.4	0.7	7.3		3.0
potato	8.0			11.3	0.4	10.6		3.0
sweet potato								1.4
apple	7.0			5.6	0.4			2.0
mandarin orange								0.3
banana								0.8
formula concentrate		8.0			0.5			
wheat bran	0.9						0.5	0.5
bread	4.6							
barley							4.0	
yoghurt								0.3

Table 2 Dry matter (DM, kg) and acid detergent lignin (ADL, g) intake

	DM	ADL		DM	ADL
giraffe	12.25	329	llama	2.10	96
cattle	24.41	1103	hippopotamus	17.55	776
sheep	0.96	60	horse	5.11	187
camel	8.56	364	tapir	4.34	185

Table 3 Digestibility (%) of dry matter (DM), crude protein (CP), acid detergent fiber (ADF) and cellulose (C) in several herbivores.

	DM	CP	ADF	C
giraffe	76.7	73.3	47.3	56.1
cattle	70.6	70.9	58.0	69.7
sheep	62.9	78.6	53.1	42.6
camel	72.3	41.6	75.3	89.8
llama	67.0	69.7	68.1	55.7
hippopotamus	52.7	61.0	45.5	52.9
horse	60.2	64.6	13.1	16.4
tapir	62.6	64.6	38.8	51.7

able.

Table 3 illustrates digestibility for DM, CP, ADF and C. DM digestibility for the ruminants, including the camelids, ranged from 62.9% to 76.7%. There was a tendency for the ruminant animals to be fed a higher percentage of concentrate and to show a higher DM digestibility. Non-ruminant animals showed less DM digestibility than the ruminants. The low DM digestibility in the hippopotamus may be due to the high proportion of roughage in the diet.

CP digestibility was higher than 61%, except for in the case of the camel. This low CP digestibility in the camel may reflect a low CP intake.

ADF digestibility among the ruminants ranged from 47.3% to 68.1%, while that in non ruminants ranged from 13.1% to 45.5%. The ADF digestibility of the giraffe, as a concentrate selector was the lowest among the ruminants. The horse and tapir, as hindgut fermentors, showed very low ADF digestibility. The hippopotamus, as a non-ruminant pregastric fermentor showed an intermediate level of ADF digestibility.

C digestibility tended to higher than ADF digestibility, except in the sheep and the llama. It also tended to be higher in the ruminants than the non-ruminants, except in the case of the sheep. The hippopotamus was found to have the highest value among the non-ruminants.

Van Soest has listed C digestibility for a number of non-ruminants[6] and cell wall or crude fiber digestibility for ruminants[7]. According to that list, C digestibility in the hippopotamus, horse and tapir is 50%-71%, 33% 66% and 29%-54%, respectively. The cell wall and crude fiber digestibility of the giraffe, cattle, sheep, camel

and llama is 56%-58%, 50%-65%, 1%-76%, 62%-63% and 48%-69%, respectively. Some of our results were within this range, although some were lower and some were higher. A direct comparison here does not seem to be appropriate, as only a limited amount of data was obtained using different feed and different methods.

In addition, ADL is not an ideal marker as its recovery in the feces is imperfect[4,5]. However, no alternative method was available under the conditions of the present study.

Only limited information was available, therefore, in the present study, as there was only one animal from each species, the variety of feed source was different and an imperfect marker was used. However, there was a tendency for the digestibility of the fiber fractions to be higher in the ruminants, including the camelids, than in the hindgut fermentors, with the hippopotamus, as a non-ruminant pregastric fermentor, showing intermediate digestibility between these two groups.

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要　　約

円山動物園で人工飼育されているキリン，ラクダ，ラマ，カバおよびバクと，酪農学園大学で飼育されているウシ，ウマおよびヒツジを各1頭を供試し，飼料構成，給与量および残飼量を連続した2日間実測した。このとき，最低2回以上，新鮮糞を採取した。粗飼料の割合は反芻動物で47～100%であり，非反芻動物で21～84%であった。

ADLは消化されないものとみなして，これを内部マーカーとして，消化率を算出した。乾物消化率は反芻動物で63～77%であったのに対し，非反芻動物では53～63%であった。粗蛋白質の消化率は42～79%の範囲にあった。ADFの消化率は反芻動物で47～75%であり，非反芻動物で13～46%であった。供試動物が少なく，飼料構成もさまざまであり，ADLのマーカーとしての信頼度も高いとはいえないが，繊維成分の消化率は概して反芻動物において高く，非反芻動物において低い傾向にあり，非反芻動物の中では前胃発酵をするカバが後腸発酵をする動物より高い傾向が認められた。