CHAPTER 5

Chemical analysis and consistency of faeces produced by captive monkeys (François langurs, *Trachypithecus françoisi*) fed supplemental fibre

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Publication
The Veterinary Quarterly (2001) 23:2 76-80

Abstract

The effect of additional dietary fibre on the consistency of faeces was studied in a group of four François langurs (*Trachypithecus françoisi)* kept in Rotterdam Zoo. To increase fibre intake, a diet pellet rich in fibre was offered instead of the usual, commercial primate pellet. This dietary change raised the amounts of hemicellulose and cellulose that were consumed at the expense of non-structural carbohydrates. The experiment had an A1-B-A2 design. Stool quality improved when the high-fibre pellet was fed. The monkeys produced somewhat more faecal dry matter and the faeces contained markedly more non-structural carbohydrates and less crude fibres when the high-fibre pellet was fed. The percentage of water in the faeces was slightly lower when the high-fibre diet was offered. We speculate that the extra fibre was partly fermented and that the breakdown products were recovered in the carbohydrate fraction of faeces. These breakdown products might have a superior water-binding capacity, leading to well-shaped faeces. This study showed that François langurs have the capacity to digest dietary fibre, as has been demonstrated earlier for other species of leaf-eating monkeys.

Key words: dietary fibre; digestion; leaf-eater monkeys.

Introduction

The François langur (*Trachypithecus françoisi*) is a herbivorous primate that inhabits the sandstone hills in the south of China and north of Vietnam. The natural diet of this primate mainly consists of various types of leaves, but fruits are also consumed (5). François langurs and other leaf-eating primates of the subfamily Colobinae have a stomach consisting of different compartments for pregastric fermentation similar to that in ruminants (1, 4). However, langurs do not ruminate (1,2,4).

Like many other langur species, the François langur is threatened by extinction both in the wild (5) and in captivity (6). To increase the survival of these species in captivity, proper dietary management is needed. Unfortunately, there is only limited information in this respect. Leaf-eating monkeys in captivity often suffer from gastrointestinal disturbances associated with diarrhoea (3). Comparison of the natural diet of leaf-eating monkeys and Western zoo diets has shown that the former contains much higher levels of fibre (6). Because of this and because the François langurs in Rotterdam Zoo produced soft faeces, a diet pellet rich in fibre was introduced to their diet.

The experimental high-fibre pellet was offered instead of the usual, commercial primate pellet. This paper reports the effect of extra fibre intake on the composition and consistency of faeces produced by the langurs.

Methods

Four François langurs were studied. There were two males aged 11 and 13 years, one female aged 13 years and one juvenile female aged 3 years. The langurs were housed together in an enclosure consisting of an indoor (5.00 x 3.50 x 3.65 m) and outdoor area (15.50 x 3.50 x 3.65 m). The outdoor enclosure had natural daylight. Lights in the indoor enclosure were on from 7.00 to 19.00 hours. The experiment was conducted between the end of May and the beginning of August 1999. The experiment had an A1-B-A2-design. The usual diet was fed during the first period (A1), the high-fibre diet was fed during the second period (B), and the usual diet was reintroduced for the last period (A2). Periods A1 and B lasted 21 days and the A2 period lasted 24 days. During the first week of periods B and A2, the pellets to be fed were gradually introduced.

Table 1. Average composition of the diet (g/kg as fed) offered to the four langurs during each period of the experiment.

Period Days	A1 (n=7)	B (n=7)	A2 (n=7)
Pellets[1]	68.6	152.6	70.9
Greens (lettuce, cucumber, fennel, celery)	176.3	224.9	154.6
Browse (willow branches, rose leaves)	557.5	458.3	576.2
Vegetables (carrot, green pepper, beetroot)	153.2	126.1	146.5
Fruits (green banana)	34.9	28.2	44.8
Egg (boiled whole)	7.4	7.6	4.9
Leaf-eater vitamins[2]	2.1	2.3	2.1
Total	1000	1000	1000

[1]Period A1 and A2 : Leaf-eater Pellets, Mazuri Zoo Foods, Witham, Essex, U.K. Composition per 100 g: moisture 10 g, crude protein 23 g, crude fat 5 g, crude fibre 11.2 g, NDF 23.7 g, ADF 15 g, calcium 1030 mg, phosphorus 670 mg, sodium 270 mg, potassium 106 mg, magnesium 210 mg, iron 39 mg, copper 2.5 mg, zinc 14.5 mg, manganese 12.5 mg, vitamin A 3000 IU, vitamin D3 660 IU, vitamin E 21mg, vitamin C 100 mg.
Period B: Experimental pellet produced by Hope Farms, Woerden, The Netherlands. Composition per 100 g: moisture 4 g, crude protein 19.8 g, crude fat 6.3 g, crude fibre 52.1 g, NDF 52.8 g, ADF 39 g, lignin 8 g, calcium 980 mg, phosphorus 420 mg, sodium 32 mg, potassium 630 mg, magnesium 48 mg, iron 35.4 mg, copper 4.2 mg, zinc 11.9 mg, manganese 13.2 mg, vitamin A 2183 IU, vitamin D3 437 IU, vitamin E 12.9 mg, vitamin C 18.3 mg.

[2]Leaf-eater vitamins per 10 g (38.7% Mervit sporavit 325, 60.5% calcium monophosphate, 0.8% vitamin: Pre Mervo 500): moisture 0.2 g, ash 5.9 g , vitamin A 41401 IU, vitamin D3 774.3 IU, vitamin E 11.6 mg, thiamine 1.6 mg, riboflavin 3.1 mg, niacin 15.5 mg, pyridoxine 1.6 mg, folic acid 774.3 μg, vitamin B12 11.6 μg, pantothenic acid 7.7 mg, choline 154.9 mg, biotin 0.04 mg, vitamin C 38.7 mg, calcium 1427.8 mg, phosphorus 1461.7 mg, magnesium 35.7 mg, potassium 4.8 mg, sodium 3.6 mg, sulphur 72 mg, iron 139.1 mg, zinc 37.3 mg, copper 3.9 mg, manganese 40.8 mg, selenium 0.08 mg, iodine 0.15 mg, cobalt 0.22 mg.

Then, the diet was kept constant, and diet and faeces samples were collected during the last 7 days of each period. Diets offered are shown in Table 1. At 8.00 hours, the monkeys were offered the diet pellets. At about 10.00 hours, they were given half of the remaining daily food, and the other half was offered at 16.00 hours.

During the last 7 days of each period, stool quality was scored daily on a scale of 1-5. The scores were defined as follows:
1 = properly shaped and generally solid,
2 = properly shaped, but soft,
3 = in part properly formed,

4 = loose faeces,
5 = liquid faeces.

As a reference for properly shaped faeces, we took the form produced by wild François langurs, as shown in a paper of Nadler (5). Scores were assigned by F.B. Duplicate samples of the diet and left-overs were collected daily for the last 7 days of each period. Faeces were collected quantitatively. All items collected were stored at – 20°C until analysis. The diet and faeces samples were dried at 60°C, pooled per period, and then ground to pass through a 1-mm screen. All samples were analysed for dry matter, nitrogen, crude fat, crude fibre, and ash using the Weende method. Crude protein was calculated as nitrogen mass times 6.25. Non-structural carbohydrate content was calculated as the residual fraction. Further, neutral- (NDF) and acid-detergent fibre (ADF) and lignin were analysed using the method described by Van Soest (9). Hemicellose was calculated as NDF minus ADF and cellulose as ADF minus lignin.

Results

Table 2 shows the amounts of macronutrients supplied, left-over and consumed. The feeding of the experimental pellet during period B raised the amounts of crude fibre, NDF and ADF in the diet that was actually consumed by the monkeys (Table 3). The amount of cellulose ingested was also increased. During period B, the concentration of non-structural carbohydrates in the diet consumed was lower than during periods A1 and A2 (Table 3).

Thus, in essence the intake of fibre during period B was increased at the expense of non-structural carbohydrates. Replacing the usual diet pellets by the high-fibre pellets did not systematically alter the amounts of other nutrients consumed. The langurs were reluctant to consume the high-fibre pellet in the beginning, but they readily consumed it, although slower, when the amount of the usual pellet was reduced and finally removed from the diet.

Table 2. Amounts of macronutrients supplied, left-over and consumed and that recovered in faeces (g/animal day)

	Supplied			Left-over			Consumed			Faeces		
Period:	A1	B	A2	A1	B	A2	A1	B	A2	A1	B	A2
Protein	53	69	54	26	31	17	28	38	37	14	12	11
Fat	12	16	14	6	7	4	6	9	9	5	7	5
Carbohydrates	178	162	166	107	87	75	70	75	92	17	38	14
Crude fibre	115	142	107	90	88	81	25	54	26	14	2	10
NDF	202	242	193	144	144	119	58	98	75	31	37	24
Hemicellulose	50	72	54	31	40	28	18	32	26	7	10	7
ADF	153	170	140	113	103	91	39	66	49	24	29	17
Cellulose	91	114	93	71	70	60	19	44	33	8	16	8
Lignin	62	55	47	42	33	31	20	22	16	15	14	9
Ash	24	27	28	12	12	11	12	14	17	8	8	7
Water	974	857	1011	253	222	300	721	636	711	196	182	158
Dry matter	382	416	369	241	225	188	141	190	181	58	67	47

The water fraction of the macronutrients supplied and consumed does not include drinking water

Table 3. Composition of the diets (g/kg dry matter) consumed by the four François langurs.

Period:	A1	B	A2
Protein	199	200	204
Fat	43	47	50
Carbohydrates	496	395	508
Crude fibre	177	284	144
NDF	411	516	414
Hemicellulose	128	168	144
ADF	277	347	271
Cellulose	135	232	182
Lignin	142	116	88
Ash	85	74	94

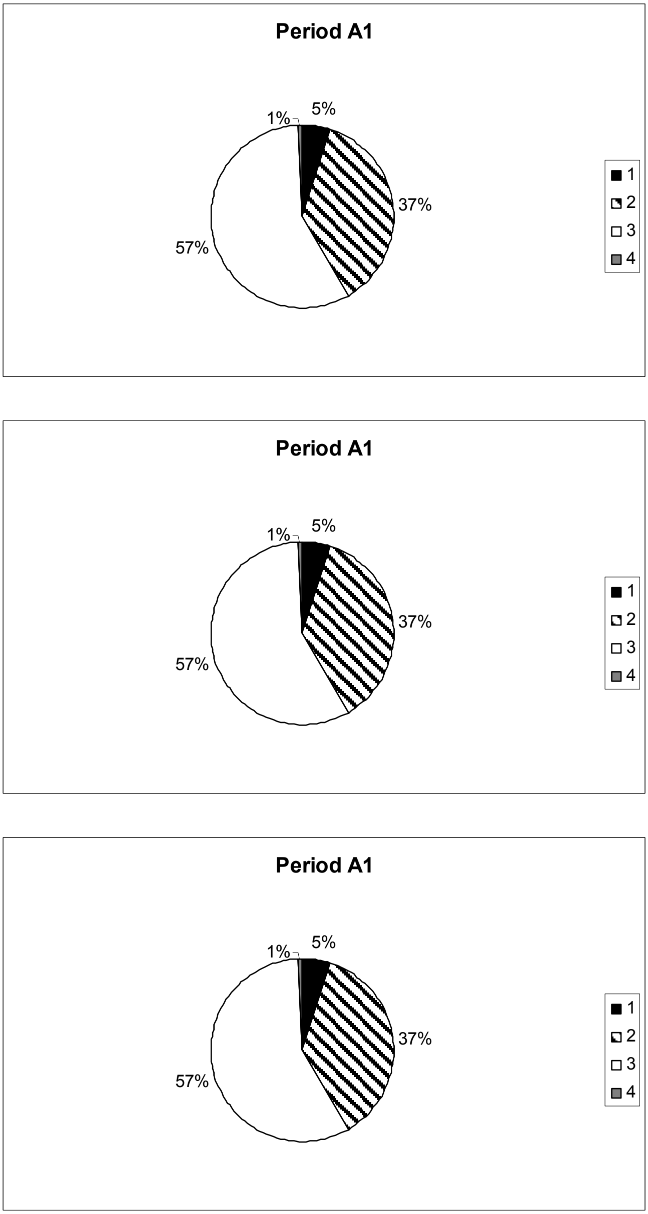


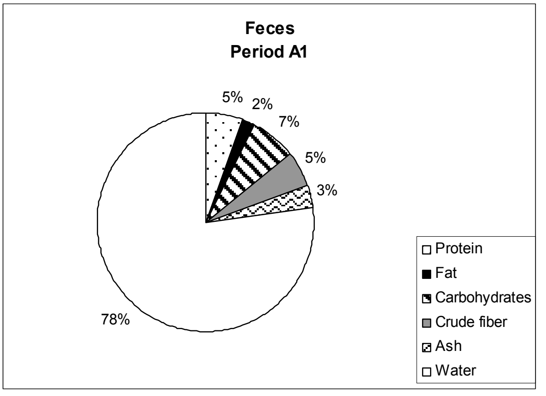
Figure 1. Proportional distribution of stool quality in periods A1 (control diet), B (high-fibre diet) and A2 (control diet). Indicated areas correspond with faecal scores: 1, properly shaped and generally solid, 2 properly shaped, but soft, 3, in part properly formed, 4, loose faeces.
The latter score was given for 1% of the faeces during period A1 only.

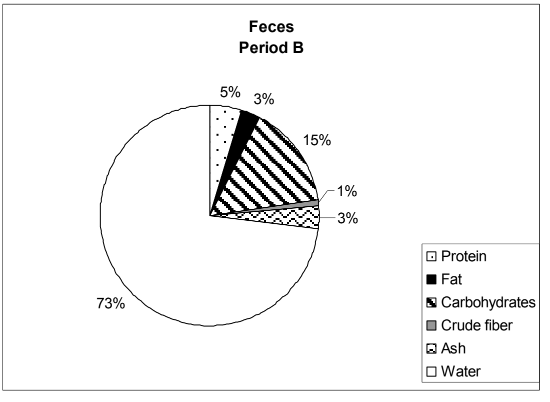
A1

B

A2

Figure 2. Typical appearance of faeces produced during the A1 (control diet), B (high-fibre diet) and A2 (control diet) periods.





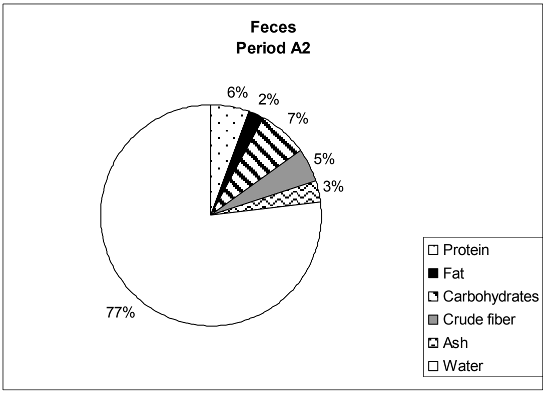


Figure 3. Proportional composition of the faeces in periods A1 (control diet), B (high-fibre diet) and A2 (control diet). Explanation of different areas:

The scores from stool quality are given in Figure 1. Stools were more properly shaped and solid when the langurs were fed the high-fibre diet. The stools were less well-shaped and solid when the usual diet was offered during either period A1 or A2.

Photographs of typical faeces also show the difference in stool quality between the B and the two A periods (Figure 2). Table 2 shows the chemical composition and amount of faeces produced.

During period B, the monkeys produced somewhat more faecal dry matter than during the A periods. The amount of faecal water was not systematically affected by the diet (Table 2), but the percentage of water in faeces was slightly lower during the B period (Figure 3). When monkeys ate the high-fibre pellets, the faeces contained more non-structural carbohydrates (15 versus 7%) and less crude fibre (1 versus 5%) than when they ate the usual pellets (Figure 3).

The data in Table 2 allow calculation of the apparent digestibility of macronutrients. Apparent digestibility is defined as nutrient intake minus faecal excretion and expressed as a percentage of intake. However, for digestibility calculations the amount of macronutrients consumed may not be sufficiently accurate because they reflect the difference between two relatively large values, i.e. the amount offered and that left over. The major portion of the left-overs contained branches from which the leaves had been removed. As a consequence, in a few cases the apparent digestibility of macronutrients, calculated as the amount consumed minus the amount recovered in faeces, may show aberrant values. The apparent digestibility of crude fibre was 96% for the experimental diet and 46% (period A1) of 62% (period A2) for the usual diet.

Discussion

From the outset, it should be stressed that his study had various limitations which relate to the use of rare, exotic animals on exhibit in a zoo. The four langurs studied were housed in a group so that the inter-individual variation in digestibility measurements could not be assessed. In addition, the animals were of different age and body weight. The provision of different food items as a mixed diet allowed for selection and thus inter-individual variation in intake. The diets consumed during the two A periods were similar, but not identical. It cannot be excluded that there was some urine contamination of faeces. Thus, the group mean data on faeces composition should be interpreted with caution, but it is reassuring that the reproducibility was acceptable, which would exclude any substantial difference in systematic and/or random error for the two A periods.

This study showed an improvement of stool quality when the François langurs were fed a high-fibre diet. The appearance of the stools during period B was similar to that observed when François langurs are in their natural habitat (5). As shown in table 3, the experimental high-fibre diet, as consumed during period B, contained 28% crude fibre, 52% NDF, 35% ADF and 12% lignin in the dry matter. In this zoo, the usual diet as consumed during periods A1 and A2, on average contained 16% crude fibre, 41% NDF, 27% ADF, and 12% lignin in the dry matter (Table 3). Diets consumed by south-east Asian colobines in nature may contain 51% NDF in the dry matter whereas diets fed to leaf-eating monkeys in Western zoos contain only 4-26% NDF (6). Thus, the high-fibre diet used in this study corresponds with the diet that may be consumed in the wild, at least with regard to the concentration of NDF.

The leaf-eating monkeys such as langurs (1, 8), proboscis monkeys (2) and colobus monkeys (7, 10) can efficiently utilise cell wall constituents. Indeed, in this study the apparent digestibility of hemicellulose and cellulose ranged between 62-73% and 57-77% of intake, respectively. Leaf-eating monkeys are often fed the same diet as are the more frugivorous monkeys and apes, which may give rise to gastrointestinal disturbances in the former (3). To maintain proper gastrointestinal function in leaf-eating monkeys the diet may have to contain high amounts of fibre. This statement is supported by the present observation in that replacement of non-structural carbohydrates by hemicellulose plus cellulose improved stool quality in François langurs.

It is difficult to see why the experimental high-fibre diet improved faecal consistency. With the experimental diet, the faeces contained slightly less water, were markedly enriched with no-structural carbohydrates, and had a lower content of crude fibre. Crude fibre consumption was about twice as high when the experimental diet was fed instead of the control diet, whereas the absolute amount of non-structural carbohydrates ingested was similar for the two diets. Possibly, the crude fibre was partly fermented so that its breakdown products were recovered in the carbohydrate fraction of faeces. The breakdown products of crude fibre might have a superior water-binding capacity, leading to well-shaped faeces. Further research could prove or disprove these ideas. In keeping with the idea of partial digestion of crude fibre, the apparent digestibility of the crude fibre was much better when the high-fibre diet was offered instead of the control diet. Our data point to an apparent digestibility of lignin of about 35 %. Although it is generally accepted that lignin can neither be digested nor fermented some authors have demonstrated that lignin apparently can be digested by leaf-eating monkeys (2, 7, 10). However, the observed digestibility of lignin has been ascribed to methodological error (9), as described by Watkins *et al.* (10). Despite this, it cannot be excluded that leaf-eating monkeys have intestinal bacteria capable of breaking down lignin.

In summary, this study shows an improvement of stool quality when François langurs were fed a high-fibre diet. However, long-term feeding trials will be necessary to determine whether a high-fibre diet can enhance the health and reproductive success in François langurs and other leaf-eating monkeys kept in captivity. This study also showed that although the langurs preferred a diet containing carbohydrates that are easily digested, they also consumed a diet containing more fibre albeit less willingly and slower.

Acknowledgements

We thank Mary Vriens, Paul de Wit, Rick van Kesteren, Iris Wessenaar and Melle Van Ieperen (Rotterdam Zoo, The Netherlands) for biotechnical assistance during the experiment.

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