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Research article

Diet review and change for monkeys at Paignton Zoo Environmental Park

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Abstract

Between 2003 and 2010 the diets of all medium-sized monkeys at Paignton Zoo Environmental Park were subjected to a continual process of review and improvement. This resulted in the removal of all fruit, bread, eggs and seeds from the diets and changes to commercial products used for some species. All species are now provided with similar diets consisting of a suitable commercial pelleted feed, a variety of fresh vegetables and small amounts of dog biscuits and cooked brown rice to provide opportunities for scatter feeding. Compared with the 2003 diets the 2010 diets have higher levels of protein (3–47% increase) and fibre (36–77% more NDF) and lower levels of readily digestible carbohydrate (6–14% decrease). Resultant health benefits have been improved dental health and weight loss in some previously overweight individuals. In addition, the 2010 diets are also considerably less expensive than the 2003 diets resulting in an estimated annual cost saving of £9717 based on current prices and animals held.

Introduction

Although primates are traditionally regarded as relatively easy to feed, there is growing recognition that inappropriate diets contribute to several common health problems seen in captive omnivorous primates (e.g. see Oftedal and Allen 1996; Schwitzer et al. 2009). Most common among these is obesity (e.g. Schwitzer and Kaumanns 2001; Videan et al. 2007), which is associated with many other illnesses such as heart disease, cancer, diabetes and reproductive problems (Register and Clarkson 2009).

Obesity can have a number of contributory factors, including low activity levels in captivity, but is largely due to captive diets that are high in energy without the foraging and digestive costs associated with the species' natural nutritive strategies (Schwitzer at al. 2009). This is particularly common in omnivorous primates, which are often fed a wide variety of food items, including fruit, vegetables, insects and vertebrate prey, reflecting assumptions about their food selection in the wild. Traditionally, most tend to be regarded as fruit eaters, at least to some extent, and are therefore fed fruit in captivity. This is even the case for some highly folivorous species. Unfortunately, fruit cultivated for human consumption is very different in terms of nutrient composition to leaves and wild fruits eaten by free-living primates (e.g. Oftedal and Allen 1996). Selective breeding and modern cultivation methods produce fruit that is high in sugars and low in fibre, and therefore high in readily digestible energy. Cultivated fruit also tends to be lower in protein, minerals and vitamins than most foodstuffs consumed by primates in the wild (see Schwitzer et al. 2009 for an excellent review). In addition to contributing to obesity, captive primate diets containing large amounts of cultivated fruit may cause gastrointestinal problems due to low fibre content (Edwards and Ullrey 1999) and poor dental health due to high sugar levels (Johnson-Delaney 2008).

Between 2003 and 2010 we underwent a continual process of review and improvement of diets fed to medium-sized monkeys at Paignton Zoo Environmental Park. These were initiated as a result of a number of different issues of concern that could be related to diet, although most of the individuals were generally healthy. The first of these, and the main trigger for diet review, was the poor dental health of several of the Abyssinian colobus (*Colobus guereza*) and king colobus (*C. polykomos*) monkeys. Following reviews of these diets, increased awareness of potential nutritional problems, particularly obesity, stimulated keepers on the section to instigate similar reviews of the diets for the rest of the monkeys in their care. Additional species present in this section of the zoo (echidna, pygmy slow loris,

Table 1. Monkey species included in diet reviews at Paignton Zoo Environmental Park between 2003 and 2010.

Species	Diet review period	Group size and structure	Main concerns
Abyssinian colobus *Colobus guereza*	March 2003–July 2008	Initially 2 family groups. Gradually phased out; 1 group of 2 males by 2010	Many individuals had serious dental problems including tooth decay and gingivitis
King colobus *Colobus polykomos*	March 2003–July 2008	Single male, multi-female plus young	Dental problems as above, but not so severe
Diana monkey *Cercopithecus diana*	April–September 2007	Adult pair plus young	Adult male overweight
Hamadrayas baboon *Papio hamadrayas*	July 2007	Large multi-male, multi-female group with many young (>50 individuals)	Cost of the diet for such a large group
Variegated spider monkey *Ateles belzebuth hybridus*	September 2007–July 2010	Adult pair, arrived at zoo 2007	Frequent loose faeces and diarrhoea
Sulawesi crested black macaque *Macaca nigra*	September 2007–July 2010	Group of mixed sex and age, 1 dominant adult male (10–15 individuals)	Frequent loose faeces and diarrhoea. Some overweight individuals

African porcupine, meerkat, sloth and red panda) were also subject to similar diet reviews over the same period but are not discussed in this paper.

Methods

Study animals

All animals studied were housed at Paignton Zoo Environmental Park, Devon, UK, and remained in their usual enclosures with normal husbandry throughout the study period. Subjects included all medium-sized monkey species included in the "Monkey Heights" section (Table 1).

Diet review process

Starting in 2003 we conducted collaborative, multi-department, nutrition meetings involving keepers on the Monkey Heights section, veterinary and research staff approximately every three or four months. Issues of concern possibly related to diets were raised by keepers, discussed and if felt necessary investigated further by the research team. A pattern very quickly emerged that the first step in any review was to assess exactly what the animals were currently eating. Dietary intake studies were initially conducted by researchers but all keepers on the section were soon trained in the method and then conducted the trials themselves.

Dietary intake

For all species the daily food intake was measured for at least five days and up to three blocks of five days over three weeks. All food items provided to the monkeys were prepared in the normal way and weighed immediately before presentation. A small amount of the same food items was placed in a desiccation dish at the same time to adjust for water loss in the leftovers. Food was presented as normal, usually in three feeds per day. Any uneaten food remaining the next day was collected and weighed along with food in the desiccation dish. Weight of remaining food was adjusted according to the desiccation rate and deducted from

Table 2. Weight of food (g, as fed) provided per individual per day for six species of monkey at Paignton Zoo Environmental Park prior to (2003) and following diet reviews (2010).

	Abyssinian colobus		King colobus		Diana monkey		Hamadryas baboon		Spider monkey		Sulawesi crested black macaque	
Food type	2003	2010	2003	2010	2003	2010	2003	2010	2007	2010	2003	2010
Primate pellet[1]	24		30		11		160	170	56		35	
Trio Munch[1]	50		50						12			
Leaf eater primate pellet[1]		24		24		40				30		70
Terrier biscuit[2]		16		16		10	33	40		16		30
Brown rice		54		54		10		20		25		35
Bread	30		30		25		40		20		30	
Seed mix[3]	5		6		30		30		20		38	
Dried fruit mix[3]	95		70						2		4	
Egg	3		58		10		11		36		9	
Fruit (apple, banana etc)	320		285		341		263		290		374	
Green leafy veg	293	450	402	450	45	475	71	156	118	325	49	338
Starchy root veg	82	363	91	363	29	75	54	156	106	325	138	150
Other vegetables	23	363	50	363	52	100	51	156	87	325	55	394

[1]Mazuri Zoo Foods, Witham, Essex, UK.
[2]Winalot mixer, Purina, Horley, Surrey, UK.
[3]Seed mix was 5% peanuts, 95% sunflower seed by weight; dried fruit mix was approximately equal weights of raisins and sultanas.

Table 3. Nutrient composition of the diets as consumed by six species of monkey at Paignton Zoo Environmental Park prior to (2003) and following diet reviews (2010). Highly digestible carbohydrate estimated by calculation (Dry matter – protein – fat – NDF – ash). ME = metabolisable energy.

	Abyssinian colobus		King colobus		Diana monkey		Hamadryas baboon		Spider monkey		Sulawesi crested black macaque	
Nutrient	2003	2010	2003	2010	2003	2010	2003	2010	2007	2010	2003	2010
Dry matter (g)	283	296	282	296	146	169	324	295	194	258	222	269
Crude protein (%)	11.7	16.4	15.9	16.4	19.8	21.2	18.9	21.7	16.9	18.4	12.9	19.0
Crude fat (%)	3.9	2.6	6.2	2.6	13.4	6.3	10.1	5.5	10.3	2.7	12.2	3.4
NDF (%)	12.6	17.2	9.7	17.2	11.5	17.9	11.2	15.8	10.5	17.6	11.9	18.2
ADF (%)	8.1	11.2	6.2	11.2	7.6	12.3	6.1	10.6	7.1	11.5	8.4	11.7
Ca (%)	0.44	0.48	0.67	0.48	0.46	0.75	1.20	1.5	0.90	0.57	0.48	0.60
P (%)	0.39	0.43	0.57	0.43	0.55	0.50	0.80	0.90	0.72	0.44	0.43	0.44
Highly digestible carbohydrate (%)	68.1	58.4	63.2	58.4	51.2	48.5	52.4	48.3	55.8	55.8	58.8	53.3
ME (kJ per day)	3765	3850	3680	3850	2385	2300	5650	4730	3180	3430	3600	3390

the provisioned weight to calculate weight of each food type consumed. Data were collected on a group basis and divided by the number of individuals to give a mean intake per individual. Following dietary changes food intake was recalculated as above.

Nutrient analysis and composition

To minimise time and cost, standard nutrient values given in Zootrition (Zootrition™, version 2.6) were used for most food items. Where these were not available food samples were subjected to laboratory analysis by an external laboratory (Eurofins, Wolverhampton). Mean daily intake of each food type per individual was entered into Zootrition and a full diet analysis performed. Readily digestible carbohydrate (sugars and starch) was estimated by calculation: 100% dry matter minus crude protein, crude fat, NDF and ash.

Recommended dietary changes

Following nutrient analysis of existing diets, some changes were recommended based on available information in the literature for the species, any issues in the group and recommended nutrient requirements (NRC 2003). Dietary changes evolved over a period of years starting with the removal of all fruit, then bread and eggs and lastly sunflower seeds. For some species the commercial pellets used were changed to increase fibre content. Fruit and dried fruit were replaced with vegetables. Vegetables were divided into three types: Group A, 'green leafy', such as cabbage, lettuce, spinach; Group B, 'other', such as celery, cucumber, peas, peppers, fennel; and Group C, 'starchy root', such as carrots, beetroot, swede, sweet potato. To make diet preparation easier the total amount of each vegetable group was stated rather than each particular type of vegetable.

Results

Dietary intake

Prior to the review process, most of the monkeys were fed a similar diet of commercial pellets, fruit and vegetables, a seed mix (peanuts and sunflower seed), a dried fruit mix (raisins and sultanas), bread and eggs (Table 2). Very little food was left uneaten by any species, so the amounts of provisioned food are similar to those actually consumed in most cases. During the diet review process all fruit and dried fruit was removed from the diets. Bread was included in the original diets because it had traditionally been donated free by local supermarkets when nearing its sell-by date. However, this had stopped and it was now being purchased at a much higher cost than providing similar grain-based nutrients via pelleted feeds; bread was therefore removed. The seed and dried fruit mixes were considered important to provide a hard-to-find scatter feed and promote foraging behaviour but are high in energy and sugar. These were replaced with alternative dry feeds; terrier biscuit and cooked brown rice. Most species were switched from primate pellet to leaf eater primate pellet to further increase fibre levels.

Nutrient composition

By 2010 the diets of all six species were higher in protein, with increases of 3–47% compared with their 2003 diet (Table 3). Fibre levels were also higher, with NDF increasing by 36–77%. Estimated levels of readily digestible carbohydrate decreased by 6–14%. With the exception of the two colobus species, fat levels also decreased substantially, largely due to the removal of sunflower seeds from the diets.

Dental health

Following dietary adjustments the frequency of dental treatment required decreased rapidly (Fig. 1). Between 1998 and 2003 there were 17 instances of treatment for dental problems including gum disease, gingivitis, tartar build up, the removal of several teeth and even one euthanasia due to extremely poor dental condition. These involved 12 different individual monkeys, all but one of which were Abyssinian colobus (Fig. 1). Following the initial changes to the diet to reduce sugar levels, the frequency of dental treatment

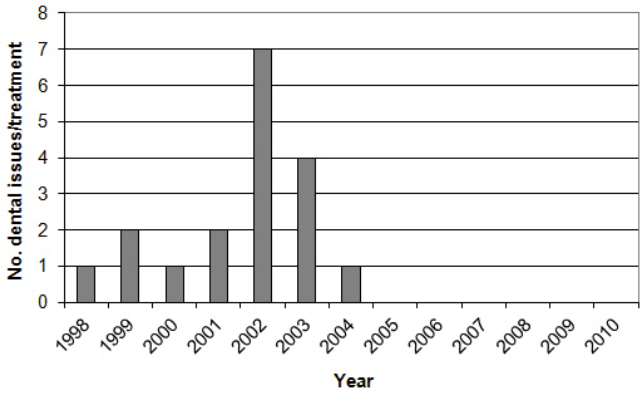

Figure 1. Frequency of dental issues identified or treatment required for six species of primate at Paignton Zoo Environmental Park before and after the initiation of diet improvements to reduce dietary sugar (March 2003).

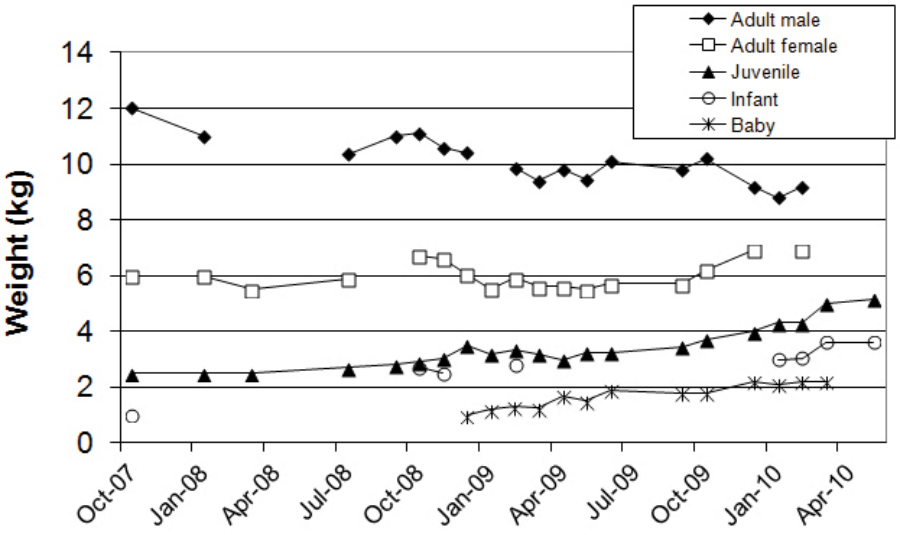

Figure 2. Body weights of a group of Diana monkeys at Paignton Zoo Environmental Park following a diet review that prompted a change from a fruit-based to a vegetable-based diet. The removal of all fruit occurred in April 2007; other changes were completed in September 2007 immediately before the first weights were obtained.

declined markedly, to the extent that veterinary intervention specifically for dental treatment has not been necessary since 2004. Dental health continues to be monitored opportunistically when monkeys are restrained for other reasons and is generally very good.

Body weights

In order to monitor the effects of diet reviews over this period, keepers on the section began to train the animals to station on weighing scales and have since been able to obtain body weights on a regular basis for most individuals. The diet changes implemented resulted in gradual but sustained weight loss of some overweight individuals within a group, whilst others maintained stable healthy weights. This was particularly noticeable in the Diana monkey group, where the overweight adult male decreased in weight from 12.0 kg in October 2007 (immediately after the first diet changes were made) to 9.2 kg in early 2010, and appeared to be stable at this weight prior to his departure to another zoo in late 2010 (Fig. 2). A similar effect was also seen in the Sulawesi crested black macaques, where three overweight individuals also showed slow, sustained weight loss whilst other members of the group maintained steady weights throughout. These were the adult male (from 17.0 kg to 14.5 kg) and two adult females, both 9.0 kg before diet changes and now 7.5 kg and 6.9 kg. These three individuals also now appear to be at a stable weight.

Faecal quality

Faeces was not formally monitored, but anecdotally keepers report that for all species, with the exception of Sulawesi crested black macaques, it has generally improved in consistency with far fewer instances of loose faeces. The Sulawesi crested macaques still have frequent diarrhoea that does not appear to be related to diet and to date remains unexplained despite extensive veterinary investigation.

Diet costs

The cost of the 2003 diet for each species was calculated using 2010 prices for each ingredient and compared with the cost of the current diet (Table 4). The 2010 diets are substantially cheaper than the 2003 diets for all species. For the total number of individuals held in 2010 these reductions in cost represent an overall saving of £9717 per year as a result of using the 2010 diets rather than the 2003 diets.

Discussion

The diet review process in the Monkey Heights section started in 2003 and has resulted in changes to most of the medium-sized monkey diets such that they now all receive a very similar diet that is higher in fibre and protein and lower in readily digestible sugars and starch than previously. During the review process, low fibre and

Table 4. Cost comparisons of the diets fed in 2003 and 2010 to six species of monkey at Paignton Zoo Environmental Park; all costs based on 2010 prices (UK £ sterling).

		Abyssinian colobus	King colobus	Diana monkey	Hamadryas baboon	Spider monkey	Sulawesi crested black macaque
Cost per monkey per year	2003 diet	441	453	291	359	331	362
	2010 diet	296	296	162	222	241	267
Group size in 2010		2	3	4	50	5	12
Total annual cost	2003 diet	882	1359	1164	17950	1655	4344
	2010 diet	592	888	648	11100	1205	3204

high sugar in largely fruit-based diets was concluded to be the most likely cause of a variety of issues of concern. All fruit was therefore removed from the diets and the amount of vegetables increased. However, some vegetables, particularly starchy root vegetables also contain high levels of readily digestible carbohydrate (e.g. Clauss et al. 2010). In order to prevent overfeeding of these vegetables types, the 'three veg group' system was devised. These three groups are green, leafy vegetables (e.g. cabbage, spinach, lettuce), starchy root vegetables (e.g. carrots, swede, squashes) and others (e.g. peas, onions, fennel). The total weight of each group is specified but keepers are free to use any vegetable type within the group to make up that weight. This, along with the fact that diets across the section are now so similar, has reduced preparation time.

In addition, because we have replaced relatively expensive fresh and dried fruit with cheaper vegetables, and increased scope for flexibility to take advantage of seasonally cheap produce and special offers, we have made substantial costs savings, estimated to be on average £129 per year per monkey, resulting in an overall saving of nearly £10,000 per year.

Although it has increased since 2003, the fibre content of the 2010 diets is still not as high as that found in items consumed by free-living monkeys (typically over 50% NDF; Oftedal and Allen 1996). However, the dietary analysis presented here does not include browse, which is very high in fibre and provided to most of the target species on a regular basis.

The main impetus for beginning diet reviews on this section was poor dental health of the colobus monkeys, which had necessitated 17 instances of restraint and anaesthetic for treatment within the previous five years. The removal of sugary fruit from their diet had an almost immediate effect, drastically reducing the need for treatment. Since 2003 there has only been one case in which an individual of the species concerned has been specifically restrained for a dental condition. The vast majority of dental issues affected the Abyssinian colobus monkeys so we would expect fewer instances now we have fewer individuals in the collection. However, until about 2007 the numbers of animals was still similar to the situation pre-2003, so there was a genuine reduction in treatment rate, at least from 2004–2007.

An unexpected result of the dietary changes was weight loss of overweight individuals within a group, whilst other animals in that group maintained healthy weights. This was achieved without taking steps to limit food intake of particular individuals, such as separating them at feeding times. These overweight individuals are the more dominant animals in the group and so are able to select and consume much more than their fair share of their preferred food items (Smith et al. 1989). When the diet included many highly desirable, sweet items, this ability to select preferred items and prevent access for other group members presumably resulted in an over-consumption of high energy items. It appears that when these highly preferred items were removed from the diet, there was much less motivation for the dominant animals to monopolise certain food types, and thus they no longer consumed more than their fair share of the group diet. Within the macaque group, the most subordinate individual is now the heaviest adult female, possibly due to higher voluntary energy intake in response to the chronic stress of being subordinate (Wilson et al. 2008).

During the process of diet review for the monkeys only very minimal human resistance to changing the diets was encountered, mostly towards the initial removal of all fruit. Possible factors limiting resistance to change could include the gradual nature of the changes over a period of time. It was also beneficial that support for review and change was generated across all relevant departments early on in the process through collaborative and consensus-building meetings, where keepers were the main drivers in determining priorities for dietary review.

Conclusions

A continual process of diet review and adjustment for all medium sized monkeys over several years has resulted in less expensive diets that better meet the nutritional needs of the animals. The most significant change made to the diets was the removal of all fruit, including dried fruit, in order to reduce the levels of readily available energy and particularly sugar in the diets.

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