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Abstract
Apparent digestibility coefficients of unprocessed animal carcass diets were determined with captive leopards (*Panthera pardus*) in the Bloemfontein Zoological Gardens. Procedures were developed to conduct digestibility trials with an adult male and a female leopard, each comprising three replications in succession per leopard. The diets comprised the unprocessed hind limbs or carcass portions of donkeys (*Equus asinus*) or horses (*E. caballus*). A carcass portion or 'trial diet', namely one of the two symmetrical hind limbs of a donkey or horse, was fed to a specific leopard and the other hind limb, the 'mirror image carcass portion' was retained and frozen pending analysis. Faeces excreted and food refused were collected, processed, frozen and stored pending analysis. Mean dry matter (DM) intake was 1.614 kg and 0.970 kg respectively for the male and female leopard, with mean apparent DM digestibility coefficients of 0.920 and 0.970. The apparent digestibility coefficients for crude protein (CP), lipids and gross energy (GE) were 0.937 and 0.973; 0.993 and 0.992; 0.939 and 0.965, respectively for the two leopards. The apparent digestibility coefficients for minerals were relatively low, respectively 0.619 and 0.811 for the male and female leopards. Apparent digestibility coefficients for food, expressed as DM, can be useful to estimate the food and nutrient intake of large African predators. Evaluating the nutritional status of free-ranging large African predators might be possible in a non-invasive manner.

Key words: *Panthera pardus*, digestibility, non-invasive techniques

Introduction

According to De Waal *et al.* (2005) there is a paucity of information on quantitative nutritional aspects of large African predators such as lions (*Panthera leo*), leopards (*P. pardus*) and cheetahs (*Acinonyx jubatus*), and in general the digestion of diets. Except some reports (Morris *et al*., 1974; Barbiers *et al*., 1982), little is available on the digestion of diets and absorption of nutrients by large African predators for conditions that closely resemble free-ranging feeding scenarios.

The leopard epitomizes the solitary cat (Mills & Harvey, 2001) and is the only large wild cat that survives near human habitation (Bothma & Walker, 1999). According to Mills & Harvey (2001) adult female leopards and their cubs, as well as those of some of the grownup daughters, have exclusive home ranges and the much larger home range of an adult male leopard overlaps with the mosaic of several such female home ranges.

Adult male leopards weigh about 60 kg and females 32 kg (Skinner & Chimimba, 2005). In some areas, adult male leopards may weigh up to 90 kg and females up to 60 kg. In the Kruger National Park, South Africa, the mean weight for males is 58 kg and 37.5 kg for females, while leopards in the coastal mountain areas are smaller; males and females weigh 31 and 21 kg respectively (Bothma & Walker, 1999).

[1] Deceased 9 October 2011.

Mills & Harvey (2001) stated that if cats are characterized by stealth and cunning, the leopard is the prototype. Furthermore, the leopard engages with the widest range of prey of any of Africa's predators. Among the cats, it is also the arch opportunists. In sub-Saharan Africa, 92 leopard prey species have been recorded, from dung beetles to an adult male eland weighing 900 kg (Mills & Harvey, 2001).

Male leopards kill prey every three days in the Kalahari and females with cubs, kill twice as frequently (Skinner & Chimimba, 2005). In Namibia, female leopards without cubs ate 1.6 kg and those with cubs 2.5 kg, while male leopards ate 3.3 kg of meat per day (Bothma & Walker, 1999). Leopards eat almost any prey that is available; the diet is more varied than the cheetah and lion (Schaller, 1972b). Leopards are very adaptable, but ungulates comprise the major part of diets. Unlike lions, leopards often kill and eat other predators such as African wild dogs (*Lycaon pictus*), cheetahs, bat-eared foxes (*Otocyon megalotis*) and lion cubs (Bothma & Walker, 1999). Generally, they do not attack each other as prey, but they do eat from the kill of other leopards. In isolated cases, however, leopards may be cannibalistic (Bothma, 1997).

Leopards prefer to hunt at night but kills also occur in the early hours of the morning and in the late afternoon (Schaller, 1972a). Like the other cats, leopards kill by strangulation. Hunting is opportunistic and hunger is the basic motivation for leopards to hunt (Mills, 1984; Bothma, 1997). Leopards, like lions, may be classified as unsuccessful hunters. In the Kruger National Park, South Africa only 16% of all leopard hunts are successful (Bothma & Walker, 1999). However, leopards adapt hunting techniques according to the availability of prey, differences in the defensive capabilities of prey and the degree of hunger (Bothma & Le Riche, 1989).

Leopards usually eviscerate the prey at the kill site and carry or drag it to suitable cover (Bothma & Walker, 1999). Small prey may be consumed entirely at the kill site. Leopards are known to cache food in trees (Skinner & Chimimba, 2005; Bothma & Walker, 1999). It may be to avoid interference from other predators while feeding, or the prey may be too big to consume in one day. If the leopard is not robbed of its food, it may take up to six days to consume the carcass of a large kill. According to Mills & Harvey (2001) the record leopard haul is a young giraffe weighing close on 100 kg; in areas of the Kalahari where trees are scarce, the leopard may drag its kill into a hole.

The objective of this study was to develop non-invasive techniques to conduct digestibility trials with captive leopards when consuming large portions of unprocessed animal carcasses that mimic the feeding processes of free-ranging large carnivores.

Material and methods

The study was conducted in the Bloemfontein Zoological Gardens (Bloemfontein Zoo) with an adult male and a female leopard (Borstlap, 2002). Like the lions (Borstlap, 2002; De Waal *et al*., 2005), the two leopards were housed in a spacious facility consisting of two brick and concrete enclosed night chambers (2.35 m x 2.6 m and 5.65 m x 2.6 m), with steel grate trapdoors leading to a large open-air leisure yard. The trapdoors are remotely controlled by a system of pulleys and cables. The leisure yard measured 729 m^2 and the ground is mostly covered with Kikuyu grass (*Pennisetum clandestinum*), landscaped with a few large rocks and tree trunks, and a shallow water pond.

Two digestibility trials (Trial 1 and Trial 2), each comprising three replications in succession per leopard (Replications 1, 2 and 3 each per trial), were performed as detailed in Table 1.

Like the lions (Borstlap, 2002; De Waal *et al*., 2005), the two leopards were weighed in a non-invasive manner. A steel grid was placed on top of the two metal beams containing the pressure cells of an electronic cattle scale and positioned in the leisure yard, in front of the trapdoor leading to the night chambers. When the steel grid was placed in the leisure yard, the leopards were uneasy and wary towards the foreign object; therefore, they were allowed a few days to get used to its presence before being weighed. After zeroing the scale, a leopard was lured with food onto the steel grid and the weight recorded. Every effort was made to avoid unnecessary disturbances and stress and the leopard were not weighed while a digestibility trial was underway. The leopards were weighed before being fed to reduce fluctuations in body weight due to gut fill.

Table 1. The schedule of digestibility trials conducted with the captive male and female leopards, being fed large portions of unprocessed donkey or horse carcasses.

Trial	Predator	Carcass type	Replication	Date
1	Male leopard	Donkey	1	3 April 2002
		Donkey	2	24 April 2002
		Donkey	3	5 June 2002
2	Female leopard	Donkey	1	9 June 2002
		Horse	2	24 June 2002
		Horse	3	26 July 2002

In the Bloemfontein Zoo the leopards were accustomed to being fed large portions of food routinely three times a week (Sundays, Wednesdays, and Fridays between 14h00 and 15h00), mimicking the feeding habits of free-ranging leopards (Borstlap, 2002). The digestibility trials with leopards followed this routine with a minimum change in the feeding routines.

In this project Borstlap (2002), specific procedures were developed to feed large sections of unprocessed animal carcasses to large African predators such as lions (De Waal *et al*., 2005), leopards and cheetahs and, very important, obtain homogenous representative samples from the same carcass for analysis (Figure 1). Borstlap (2002) provided a detailed, step-by-step protocol or guide to conduct intake and digestibility trials with large predators in captivity.

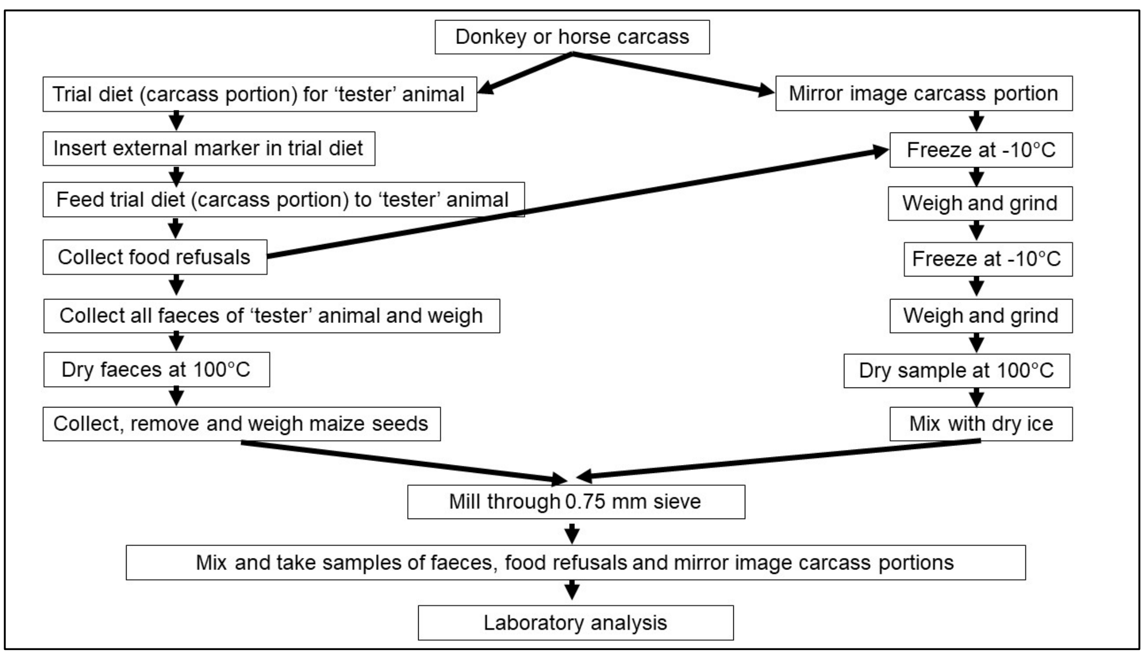

Figure 1 A schematic presentation of the experimental procedures followed in determining the food intake and digestibility trials with large African predators (Borstlap, 2002).

The diets consisted of two symmetrical portions of donkey or horse carcasses that were divided into paired sections, *e.g.* the two hind limbs of a carcass (Borstlap, 2002). Leopards, like lions, have a destructive feeding habit; therefore, one limb section was fed to a specific leopard (‘trial diet’) and the other symmetrical limb section (‘mirror image carcass portion’) was retained for analysis. It was assumed the mirror image carcass portion retained in each trial was identical in nutrient composition to the corresponding symmetrical trial diet offered to a leopard.

The donkeys (*Equus asinus*) or horses (*E. caballus*) were humanely harvested with a silenced rifle on a nearby farm and transported to the Bloemfontein Zoo. After eviscerating, but not skinning the donkey or horse carcasses, the hind limbs were severed by cutting between the last lumbar and first sacral vertebrae before the pelvis. A butcher’s meat saw was used to cut through the length of the sacral vertebrae to separate the two hindquarters, thus yielding two mirror images of a hindquarter each. The lower part or the hind leg was removed by cutting through the heel joint just below the tibia above the tarsus. The trial diet and corresponding mirror image carcass portion were weighed on a large platform scale. The mirror image carcass portions were sealed in large plastic bags, frozen and stored at -10°C pending further processing and analysis.

The two leopards shared facilities in the Bloemfontein Zoo; therefore, like with the two lions (De Waal *et al*., 2005) an additional method of identification was used with an external marker to lace or mark the faeces of one individual. Thirty yellow maize (*Zea mays*) seeds were inserted into each trial diet before being offered to a leopard (‘tester’ leopard). Furthermore, the leopard (‘filler’ leopard) that was not participating in that specific digestibility trial was fed either chicken tripe or part of a skinned donkey ribcage. The dual system of identification made it easy to distinguish between the faeces of the two leopards.

The procedures have been described in detail (Borstlap; 2002; De Waal *et al*., 2005), but in the interest of completeness it is detailed again. Before feeding for a trial commenced between 14h00 and 15h00, the two leopards were lured into separate night chambers and closed behind trapdoors. The leisure yard was inspected and all faeces, food refusals and bone remaining from previous meals removed.

The ‘filler’ leopard’s food (skinned donkey or horse ribcage or chicken tripe) was placed in the leisure yard, the service gate closed remotely and locked. The trial diet, marked in advance with 30 maize seeds, was then placed in a vacant night chamber and after closing and locking the gate, the ‘tester’ leopard was allowed to start feeding on the trial diet and the time recorded. The ‘filler’ leopard was then released back into the leisure yard to start feeding on its meal. The ‘tester’ leopard stayed overnight in its night chamber to allow it to consume as much of the trial diet as possible and to prevent the ‘filler' leopard from feeding on the trial diet. This prolonged separation of the leopard while feeding was the only deviation in the trial routine from the usual feeding routine practiced in the Bloemfontein Zoo.

The next morning, remains of the trial diet not consumed (food refusals) was collected, sealed in plastic bags, weighed, frozen and stored at -10°C pending further processing.

All faeces excreted by the ‘tester’ leopard were collected from early in the morning the day after the trial diet was consumed. The time of faecal collection was recorded. Inspections for freshly voided faeces were made at 3-hour intervals during daylight only to minimise disturbance of the leopards. The faeces were picked up with a large metal spatula, sealed in airtight plastic bags, weighed, frozen and stored at -10°C. Visible contamination of faeces with grass, twigs and soil were removed before weighing. Only faeces of the ‘tester’ leopard originating from the trial diet were collected. Faeces originating from a specific trial diet were usually excreted within 48 to 72 hours from offering the meal.

The frozen mirror image carcass portions and food refusals from the trial diets were taken from cold storage, cut into smaller pieces with a butcher’s meat saw (to fit in the holding chamber of an animal carcass grinder) and then kept frozen again. The smaller frozen carcass

pieces were removed one by one from the freezer and ground through a heavy duty, animal carcass grinder. The 64 circular grinder blades produced considerable heat (friction) during the process of grinding the frozen carcass pieces, comprising flesh, bone, skin, and hair and a substantial amount of water was lost in the form of visible water vapour or steam. This water loss was estimated by difference in weight to correct the DM content of the sample.
After thoroughly mixing the ground animal material (mirror image carcass portions and food refusals), representative samples were taken, weighed in duplicate on pre-weighed stainless-steel pans and dried at 100°C for 16 hours in a force draught oven to determine the DM content.

Representative samples of the ground carcass material and food refusals were mixed in a ratio of 1:1 (v:v) with crushed dry ice (frozen CO_2) and ground through a 0.75 mm sieve in a conventional Wiley mill. The dry ice kept the samples very cold and prevented the fat from smearing too much during the grinding process. The ground samples were stored in plastic containers with screw-on lids at -10°C pending analysis.

The faeces collected during a trial were dried separately on stainless steel trays at 100°C for 16 hours in a force draught oven and the DM content determined. The maize seeds were removed and weighed, and the weight subtracted from the dry mass of the faeces. The dried faeces were ground through a 0.75 mm screen in a conventional Wiley mill, mixed and representative samples stored in plastic containers with screw-on lids pending analysis.

The CP content of samples was determined on a DM basis with a Leco® nitrogen (N) analyser (Leco® Corporation, 2001). A factor of 6.25 was used to convert the N content of samples to CP content (McDonald *et al*., 2011). The lipid content of samples was determined in a Soxhlet apparatus, using the hexane method (AOAC, 2000). The mineral (ash) content of samples was determined on a DM basis by incinerating samples in duplicate in porcelain crucibles for 4 hours at 600ºC in a muffle furnace (AOAC, 2000). The gross energy (GE) of samples was determined on a DM basis with an adiabatic bomb calorimeter (dds CP400 calorimeter by digital data systems c.c.) (AOAC, 2000).

In each trial, the nutrient composition of the food and the nutrient intake of the 'tester' leopard were determined by subtracting the total quantity (expressed in kg) of DM, CP, lipids, minerals and GE in the refusals from that contained in the mirror image carcass portions.

The apparent digestibility of food, or nutrients, is best defined as the proportion of ingested food, or nutrients, not excreted in the faeces and, therefore, assumed to be absorbed by the animal (McDonald *et al*., 2011) and calculated as follow:

$$\text{Apparent digestibility coefficient} = \frac{(\text{Food or nutrient intake}) - (\text{Food or nutrient excreted in faeces})}{\text{Food or nutrient intake}}$$

Where intake (kg) = (kg food or nutrient presented) – (kg food or nutrient refused)

The descriptive statistics were generated using Proc Means (SAS, 1991).

Results

It is difficult and dangerous to weigh large predators without the individuals being properly restrained or chemically immobilised. Therefore, in this study the two leopards were weighed only once with the non-invasive procedure described previously; the male leopard weighed 53.0 kg and the female 35.0 kg.

Enough stock of donkeys was not available at a certain stage of the study; therefore, two horses were sourced by the ALPRU research team to conduct the last two replications with the female leopard (Borstlap, 2002).

The composition of the donkey or horse carcass portions fed to the two leopards during the two digestibility trials, each comprising three replications per leopard, is shown in Table 2.

Table 2. Nutrient composition and energy content of the donkey or horse carcass portions[1] fed to the two captive leopards (*P. pardus*) during the two trial periods.

Trial	Lion	Replication	Dry matter (DM) g/kg	Crude protein (CP) g/kg DM	Lipids g/kg DM	Minerals g/kg DM	Gross energy (GE) MJ/kg DM
1	male	1[2]	356	575	216	185	21.971
		2[2]	356	575	216	185	21.971
		3[2]	341	632	173	183	21.406
2	female	1[2]	385	497	213	270	19.187
		2[3]	284	700	152	136	22.620
		3[3]	394	555	210	202	22.507

[1] Based on the analysis of the six symmetrical 'mirror image carcass portions' that were retained while the corresponding six carcass portions ('trial diets') were fed to the leopards.
[2] Donkey carcasses portions.
[3] Horse carcasses portions.

The feed intake, faeces excreted and apparent digestibility coefficients for the male and the female leopards fed diets of unprocessed donkey or horse carcass portions, expressed on a fresh and a DM basis respectively, are presented in Table 3 and Table 4.

Table 3. Fresh food intake, the faeces excreted and apparent digestibility coefficients of diets consisting of donkey or horse carcass portions (expressed on a fresh, or as fed, basis) by a male and female leopard.

Trial 1				Trial 2			
Male leopard				Female leopard			
Replication	Fresh food intake kg	Fresh faeces excreted kg	Digestibility coefficient	Replication	Fresh food intake kg	Fresh faeces excreted kg	Digestibility coefficient
1[1]	5.200	0.314	0.940	1[1]	3.951	0.126	0.968
2[1]	4.946	0.262	0.947	2[2]	3.464	0.084	0.976
3[1]	6.926	0.349	0.950	3[2]	3.076	0.182	0.941
Mean	5.691	0.308	0.945	Mean	3.497	0.131	0.962
SD	1.077	0.044	0.005	SD	0.438	0.049	0.018
CV	18.933	14.210	0.546	CV	12.537	37.866	1.918

[1] Donkey carcass portions.
[2] Horse carcass portions.

The nutrient composition and energy content of the food ingested by the male and the female leopards fed diets of unprocessed donkey or horse carcass portions are presented in Table 5.

The CP, lipid, mineral and energy intake, faeces excreted and apparent digestibility coefficients for CP, lipids, mineral and energy by the male and the female leopards fed diets of unprocessed donkey or horse carcass portions are presented in Tables 6 to 9.

The nutrient composition and energy content of the faeces collected from the male and the female leopards fed diets comprising large portions of unprocessed donkey or horse carcass portions are presented in Table 10.

The water intake derived from their diets by the male and the female leopards fed unprocessed donkey carcass portions is presented in Table 11.

Table 4. Dry matter (DM) intake, faeces excreted and apparent DM digestibility coefficients of diets consisting of donkey or horse carcass portions by a male and female leopard.

Trial 1				Trial 2			
Male leopard				Female leopard			
Replication	Dry matter (DM) intake kg	Dry matter (DM) excreted kg	Digestibility coefficient	Replication	Dry matter (DM) intake kg	Dry matter (DM) excreted kg	Digestibility coefficient
1[1]	1.495	0.118	0.921	1[1]	1.305	0.044	0.966
2[1]	1.418	0.097	0.932	2[2]	0.812	0.026	0.968
3[1]	1.929	0.179	0.907	3[2]	0.793	0.050	0.937
Mean	1.614	0.131	0.920	Mean	0.970	0.040	0.957
SD	0.275	0.043	0.012	SD	0.290	0.013	0.017
CV	17.056	32.657	1.350	CV	29.935	31.602	1.818

[1] Donkey carcass portions.
[2] Horse carcass portions.

Table 5. The nutrient composition and energy content of the food ingested from diets consisting of donkey or horse carcass portions by a male and female leopard.

Trial	Leopard	Replication	Dry matter (DM) g/kg	Crude protein (CP) g/kg DM	Lipids g/kg DM	Minerals g/kg DM	Gross energy (GE) MJ/kg DM
1	Male	1[1]	287.437	719.410	234.955	54.296	24.956
		2[1]	286.777	712.956	227.101	88.845	23.781
		3[1]	278.471	791.207	159.599	68.744	23.836
2	Female	1[1]	330.324	443.162	203.851	326.497	16.859
		2[2]	234.486	800.429	124.855	71.026	23.413
		3[2]	257.693	867.377	147.888	47.567	26.5885
	Mean		279.198	722.423	183.041	109.496	23.239
	SD		32.253	148.266	45.255	107.274	3.333
	CV		11.552	20.523	24.724	97.971	14.342

[1] Donkey carcass portions.
[2] Horse carcass portions.

Discussion

In all three trials with the male leopard being the 'tester', the whole carcass portions fed as the trial diets were consumed. Only the large bones were left uneaten. The female leopard, however, tended to leave some of the trial diets as refusals. The female leopard ate most of the meat underneath the skin, leaving the skin and hair uneaten. The mean fresh food intake per feeding was 5.691 kg and 3.497 kg for the male and female respectively and it constituted 10.7% and 10% of the body weight of the male and female respectively.

Table 6. The crude protein (CP) intake, faeces excreted and the apparent CP digestibility of diets consisting of donkey or horse carcass portions by a male and female leopard.

Trial 3				Trial 4			
Male leopard				Female leopard			
Replication	Crude protein (CP) intake kg	Crude protein (CP) excreted kg	Digestibility coefficient	Replication	Crude protein (CP) intake kg	Crude protein (CP) excreted kg	Digestibility coefficient
1[1]	1.075	0.064	0.940	1[1]	0.578	0.024	0.958
2[1]	1.011	0.051	0.950	2[2]	0.650	0.009	0.985
3[1]	1.526	0.121	0.921	3[2]	0.688	0.017	0.975
Mean	1.204	0.079	0.937	Mean	0.639	0.017	0.973
SD	0.281	0.037	0.015	SD	0.055	0.007	0.014
CV	23.298	47.383	1.578	CV	8.686	42.959	1.397

[1] Donkey carcass portions.
[2] Horse carcass portions.

Table 7. The lipid intake, faeces excreted and the apparent lipid digestibility of diets consisting of donkey or horse carcass portions by a male and female leopard.

Trial 3				Trial 4			
Male leopard				Female leopard			
Replication	Lipid intake (kg)	Lipid excreted (kg)	Digestibility coefficient	Replication	Lipid intake (kg)	Lipid excreted (kg)	Digestibility coefficient
1[1]	0.351	0.004	0.988	1[1]	0.266	0.000	0.998
2[1]	0.322	0.001	0.997	2[2]	0.101	0.001	0.991
3[1]	0.308	0.002	0.995	3[2]	0.117	0.002	0.986
Mean	0.327	0.002	0.993	Mean	0.162	0.001	0.992
SD	0.022	0.002	0.005	SD	0.091	0.001	0.006
CV	6.756	78.108	0.473	CV	56.220	55.843	0.603

[1] Donkey carcass portions.
[2] Horse carcass portions.

In Namibia, it was noted that female leopards with cubs ate 2.5 kg, females not nursing ate 1.6 kg and males ate 3.3 kg of meat per day (Bothma & Walker, 1999). Before feeding, the leopard usually uses its incisors to remove the hair or fur of the prey animal and leave it in a neat pile (Bothma & Walker, 1999). In this study, the male leopard was not observed to feed in this way, but the female leopard did follow the procedure described by Bothma & Walker (1999).

The food intake, faeces excreted and apparent digestibility of the trial diets by a male and female leopard on a DM (DM) basis are shown in Table 4. Morris *et al.* (1974) using a venison-based diet and Barbiers *et al*. (1982) respectively reported apparent DM digestibility coefficients of 0.782 and 0.799 by leopards, using a minced meat-based commercial diet and chromium oxide as external marker.

Table 8. The mineral intake, faeces excreted and the apparent mineral digestibility of diets consisting of donkey or horse carcass portions by a male and female leopard.

Trial 3				Trial 4			
Male leopard				Female leopard			
Replication	Mineral intake (kg)	Mineral excreted (kg)	Digestibility coefficient	Replication	Mineral intake (kg)	Mineral excreted (kg)	Digestibility coefficient
1[1]	0.081	0.033	0.591	1[1]	0.426	0.013	0.970
2[1]	0.126	0.037	0.704	2[2]	0.058	0.010	0.834
3[1]	0.133	0.058	0.561	3[2]	0.038	0.014	0.630
Mean	0.113	0.043	0.619	Mean	0.174	0.012	0.811
SD	0.028	0.013	0.075	SD	0.219	0.002	0.171
CV	24.716	31.253	12.157	CV	125.812	18.737	21.043

[1] Donkey carcass portions.
[2] Horse carcass portions.

Table 9. The gross energy (GE) intake, the GE of the faeces excreted and the apparent GE digestibility coefficient of diets consisting of donkey or horse carcass portions by a male and female leopard.

Trial 3				Trial 4			
Male leopard				Female leopard			
Replication	Gross energy (GE) intake (MJ)	Gross energy (GE) excreted (MJ)	Digestibility coefficient	Replication	Gross energy (GE) intake (MJ)	Gross energy (GE) excreted (MJ)	Digestibility coefficient
1[1]	37.300	2.752	0.926	1[1]	22.003	0.833	0.962
2[1]	33.731	1.587	0.953	2[2]	19.017	0.389	0.980
3[1]	45.973	2.915	0.937	3[2]	21.075	0.960	0.954
Mean	39.001	2.418	0.939	Mean	20.699	0.727	0.965
SD	6.296	0.724	0.013	SD	1.528	0.300	0.013
CV	16.143	29.949	1.435	CV	7.384	41.175	1.330

[1] Donkey carcass portions.
[2] Horse carcass portions.

Like the case with the lions (Borstlap, 2002; De Waal *et al*., 2005), the apparent digestibility of fresh food (Table 3) was higher than the apparent digestibility when expressed on a DM basis (Table 4).

Table 11. Water intake derived from the diets consisting of unprocessed donkey or horse carcass portions by a male and female leopard.

Leopard	Water intake derived from the trial diets kg	Water intake as a percentage of body weight %	Water intake per metabolic size kg/kgW$^{0.75}$
Male	4.077	7.7	0.208
Female	2.527	7.2	0.177

The low coefficients of variation found in these trials for the apparent digestibility of fresh (Table 3) and DM (Table 4) in food suggest that there was a high measure of repeatability in the techniques applied.

Barbiers *et al*. (1982) obtained apparent CP digestibility coefficient of 0.873 by leopards using a meat-based commercial diet and Morris *et al*. (1974) using a venison-based obtained an apparent CP digestibility coefficient of 0.889 by leopards. The apparent CP digestibility coefficients (Table 6) observed in this trial are relatively higher for the male (0.937) and female (0.973) leopards, but within reasonable limits from values reported by Barbiers *et al*. (1982) and Morris *et al*. (1974).

Barbiers *et al*. (1982) reported a mean lipid digestibility coefficient of 0.972 for leopards using a minced meat-based diet. The apparent lipid digestibility coefficient (Table 7) observed in this trial for both the male (0.993) and female (0.992) leopards concur with Barbiers *et al*. (1982).

The apparent digestibility coefficients for minerals (Table 8) are high when compared to the lions, considering that both the male and female leopards are adults and do not have a high mineral requirement, *e.g.* calcium and phosphorus for bone growth. However, like for lions (Borstlap, 2002; De Waal *et al*., 2005) a situation may have occurred, namely that large bone fragments ingested previously might have been retained longer in the gastro-intestinal tract. However, one would not expect such a scenario during every meal presented to the leopards.

Barbiers *et al*. (1982) reported apparent a GE digestibility of 0.891 for leopards using a meat-based commercial diet.

The apparent GE digestibility coefficients observed (Table 9) in this trial for both the male (0.939) and female (0.965) leopards are relatively higher than values reported by Barbiers *et al*. (1982).

Field data on the aspects of food passage, digestion and defecation by leopards is scarce. In the southern Kalahari it has been documented that most of the undigested food of leopards appears in the faeces on the first day after ingestion, leopards have also been noticed to defecate only five days after ingestion of food (Bothma, 1997). Furthermore, according to Bothma (1997) the food retention time does not differ according to the prey species consumed. When leopards feed for several days on a large prey, they may defecate close to the carcass. However, it is not clear whether the contents of the faeces of a particular dropping are from the previous ingested meal.

According to Bothma & Le Riche (1994) the mean interval between defecation is 0.6 days for male leopards and 1.2 days for females in the southern Kalahari. The reason for the marked difference is not known. This is in contradiction to the belief or perception that a higher metabolic rate and thus rate of passage is assumed because of the smaller body size of female leopards. The distances travelled between defecations vary quite considerably. Male leopards travel a mean of 12.4 km between defecations and females 21 km. Again, it is not certain if the faeces of a particular defecation comprise the undigested material of the last feeding. The higher frequency of defecation by male leopards, as well as the shorter distances travelled between defecations, may be attributed to the territoriality of male leopards and the activity of defecating in the process of marking their territory.

Leopards are territorial animals in that both the male and the female defend their territories (Skinner & Chimimba, 2005). On one occasion during this study it was observed that the male leopard has defecated on top of a previous excrement of the female. The excrements were clearly distinguishable by the different colour of the faeces originating from the trial diet fed to the male leopard 'tester' and the chicken tripe fed to the female leopard 'filler'. It was also noted that the faeces were deposited on the walking trails in the leisure yard, perhaps a further indication that these animals mark their territories with faeces (Borstlap, 2002).

Like for the lions (Borstlap, 2002; De Waal *et al*., 2005), the consistency and colour of the leopard scats changed after feedings throughout the collection period.

The mean faecal CP content of 499.533 g/kg shows the extent to which indigestible hair originating from the carcass portions passes through the digestive system of leopards. On the other hand, the low mean faecal lipid content of 21.950 g/kg shows the large extent to which lipids are digested and absorbed in the digestive tract. The faecal mineral content is largely due to the pieces of indigestible bone passing through the digestive tract.

The water content may account for 85% of the total mass of prey animal bodies (Green *et al*., 1984). Therefore, like lions, leopards may obtain sufficient water from blood and soft tissue of prey animals to meet a considerable part of their water requirements. The data (Table 11) confirmed that leopards do obtain a considerable amount of water from their diets.

The results of the digestibility trials with leopards have shown that these obligate carnivores are well adapted to ingest and digest animal bodies. Leopards utilise their food and its nutrient content very efficiently.

Currently no method is available to determine the food intake of free-ranging large predators such as leopards or African lions. The procedures used in this study can assist in yielding estimates of the food and digestible nutrient intake of free-ranging leopards. However, it remains a daunting challenge to observe and track a leopard at close quarters to keep note of feedings and subsequent dropping of faeces, especially in some environments. All the faeces voided must be collected to increase the accuracy of estimating food and digestible nutrient intake. Due to the time interval it may take to collect fresh faeces excreted by a specific leopard without risk and the varying rate at which water evaporates from the faeces until it is collected, the DM content of faeces should be used in estimating food intake.

If such information is available and the techniques described above applied judiciously and further refined, the food and nutrient intake of large African predators can be estimated. Thus, nutritional status of leopards can be determined in a non-invasive manner during the different physiological stages of their lives.

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