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RESEARCH ARTICLE

Diet Composition, Food Intake, Body Condition, and Fecal Consistency in Captive Tapirs (*Tapirus* spp.) in UK Collections

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Intake measurements were carried out in 22 tapirs from seven UK zoological collections. Dry matter intake (DMI) ranged from 48 to 86 g/kg$^{0.75}$/d. Across collections, the highest proportion of the ingested diet consisted of pelleted feeds (including grains and bread) at 46$\pm$17% DMI, followed by commercial produce at 26$\pm$12% DMI, roughage (excluding browse) at 17$\pm$11% DMI, and browse at 11$\pm$11% DMI. The proportion of roughage, crude protein, crude fiber, and neutral detergent fiber levels in the diets investigated were well below levels recommended for domestic horses and other ungulates. Intakes of digestible energy (DE) as estimated from food nutrients using of a standard equation for domestic horses ranged from 0.58 to 0.88 MJ/DE/kg$^{0.75}$/d, with many individuals exceeding the assumed maintenance requirement of 0.6 MJ/DE/kg$^{0.75}$/d for hindgut fermenters. At values exceeding this DE intake, animals had higher than ideal body condition scores (BCS). Animals with higher BCS (i.e. more obese animals) generally had higher fecal scores (FS) (i.e. softer feces), and both BCS and FS were positively correlated to DMI and calculated DE intake. This suggests that the population studied was generally overfed, with resulting obesity and softer fecal consistency. The use of highly digestible feeds such as commercial produce and pelleted feeds should be restricted in the diets of these animals and roughage intake promoted in order to attempt to achieve normal BCS and FS in this captive population. Zoo Biol 28:279–291, 2009. © 2009 Wiley-Liss, Inc.

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INTRODUCTION

In the wild, tapirs feed predominantly on browse items, and also on wild fruits [Terwilliger, 1978; Williams and Petrides, 1980; Bodmer, 1990; Naranjo, 1995; Salas and Fuller, 1996; Henry et al., 2000; Downer, 2001; Galetti et al., 2001; Tobler, 2002; Aldan et al., 2004; Torres et al., 2004]. Although data on the specific nutrient composition of fruits ingested by tapirs in the wild is largely missing, it can be assumed that, like most other wild fruits, they differ markedly in nutrient composition from commercial produce [Oftedal and Allen, 1996; Oftedal et al., 1996; Schmidt et al., 2005]. Together with the browsing rhinoceroses, tapirs represent the only extant browsing perissodactyls [Clauss et al., 2008a]. The feeding of captive browsers is often considered particularly challenging, mostly owing to the difficulty of providing adequate amounts of appropriate, palatable roughage items [Clauss and Dierenfeld, 2008]. For tapirs, problems with the acceptance of hays, in particular grass hay, have been reported [Foose, 1982] and linked to the inability of their dentition to adequately comminute this material [Hummel et al., 2008].

Historically, the diets of these species were found to vary enormously between different collections. All of the collections surveyed across Europe and the US in 1970 [Wilson and Wilson, 1973] included fruit and vegetables in the standard diet, along with a type of grain, hay, and a vitamin/mineral supplement, with milk and bread also commonly fed. A more recent survey into the diet of captive lowland tapirs (*Tapirus terrestris*) in Argentina showed that, on average, diets in captivity are made up of 33% forage, 18% complete feed, and 49% of other ingredients such as grains, fruits, and vegetables on an as fed basis [Diz, 2006]. Such practices are at severe odds with the feeding guidelines for tapirs by Lintzenich and Ward [1997], who recommend that roughages should represent 70% of the ingested dry matter (DM). Additionally, reports on the activity budgets of captive tapirs [Mahler, 1984] and their fecal consistency [Lang et al., 2005] suggest that these feeding recommendations are not always followed. Therefore, in order to assess the current feeding practices for captive tapirs in the UK, we conducted a series of intake measurements across seven zoological collections.

MATERIALS AND METHODS

Animals

Nine *T. indicus* and 13 *T. terrestris* from seven zoological collections in the United Kingdom were investigated in this study, between June and July 2007. Body weights (BW) of seven animals were taken during the trial; the BW of the remaining animals were estimated through the use of photographic documentation and comparison with those animals that had been accurately weighed. Three animals were housed individually, 16 animals were housed and fed in pairs and one group consisted of three animals. To each animal, a body condition score (BCS) (Table 1, Fig. 1) was assigned based on the appearance of the ribs, back, neck, shoulders, tailhead and hips; a fecal score (FS) (Table 2, Fig. 2) was

TABLE 1. Body condition score (BCS) for captive tapirs (*T. indicus* and *T. terrestris*) developed for this study

BCS	General	Ribs	Back	Neck/shoulder	Hip/tailhead
1	Bony, skeletal	Very prominent and easily visible	T.i.: prominent ridge, T.t.: very prominent ridge	Emaciated, bony structure of shoulders and neck extremely visible	Prominent tailhead, hip, and pelvic bones
2	Thin	Prominent	T.i.: ridge defined, T.t.: prominent ridge	Thin neck and shoulders	Flat tailhead, hip, and pelvic bones
3	Moderate/fit	Not visible	T.i.: flat, no crease evident, T.t.: ridge present	Moderately thick neck, shoulders flat	Moderate fat around tailhead, flat pelvic and hip bones
4	Fat, plump	Not visible	T.i.: inverted crease, T.t.: slight ridge present	Thick neck, shoulders slightly rounded, fat deposits evident	Fat around tailhead, hips rounded
5	Obese	Not visible	T.i.: prominent inverted crease, T.t.: no crease/ridge evident	Thick neck, rounded shoulders, fat deposits extremely evident	Excessive fat around tailhead, hips, and pelvic bones very rounded, rotund

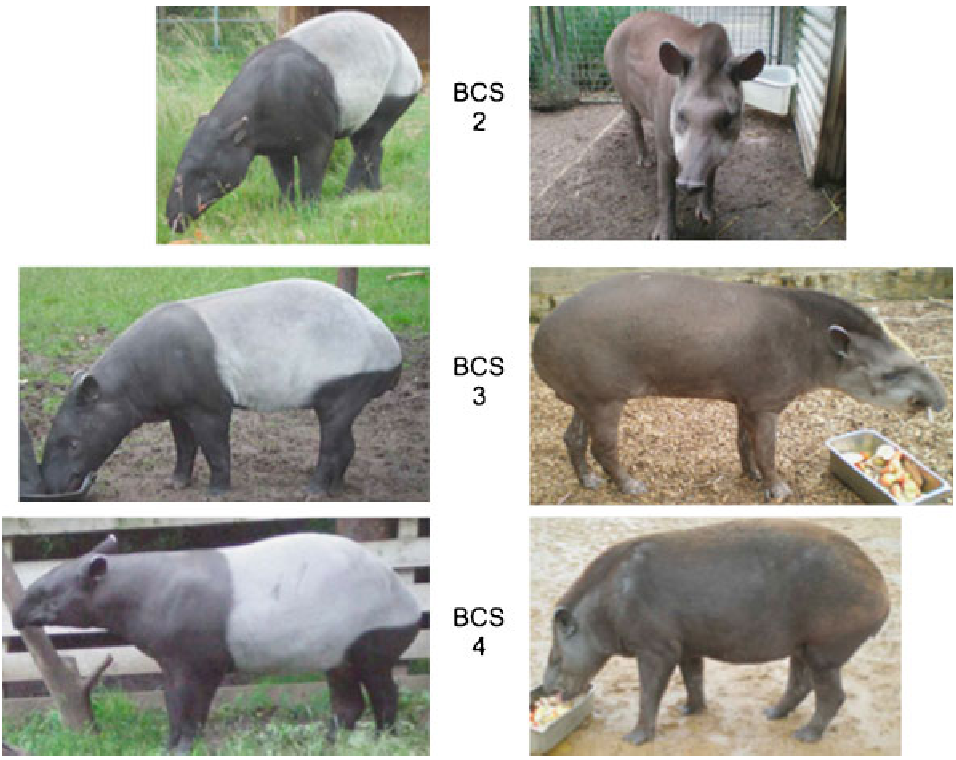

Fig. 1. Examples of body condition scores (BCS) in Malayan and Lowland tapirs (for a description of BCS, see Table 1).

TABLE 2. Feces consistency score (FS) for captive tapirs developed for this study

FS	Description
1	Dry, hard, small compact balls with no signs of breakage
2	Dry, small compact balls with some signs of breakage
2.5	Small loose balls with a high proportion of breakage and a slightly moist appearance
3	Large loose balls, moist, frequent breakage
4	Coherent mass with suggested ball formation, moist
5	Moist, coherent mass of "pie" consistency without trace of ball formation

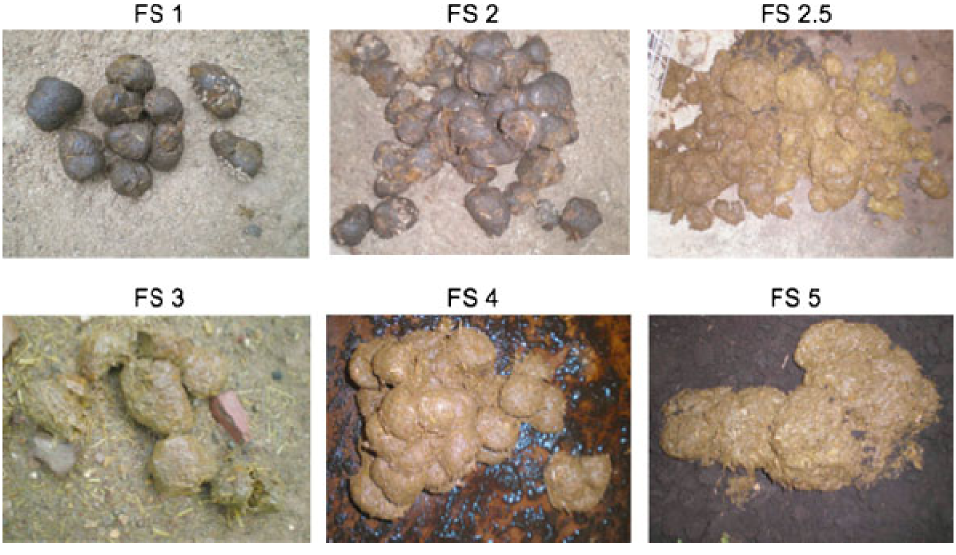

Fig. 2. Examples of fecal scores (FS) in captive tapirs (for a description of FS, see Table 2).

assigned to each observed defecation and a mean calculated for each animal. For the FS, a photograph of "normal" feces from a free-ranging South American tapir was available by courtesy of P. Medici (Fig. 3). From the medical records kept at each zoo, the occurrence of incidents of lameness, diarrhea, colic, vomitus, or obstipation was checked for each animal.

Intake Study

Food intake of individuals and groups was measured over a consecutive 3-day period by weighing individual food items offered and subtracting the weight of the leftovers on a daily basis. For a more accurate calculation of the amount of browse consumed, a representative branch of browse was placed adjacent to the corresponding enclosures and re-weighed after the time period representative of the feeding period in order to estimate the desiccation rate. Across collections, it was found that leftovers of concentrate feeds/produce were generally negligible (only traces in the corners of the troughs), hence, there was no need to perform desiccation

Fig. 3. Feces from free-ranging lowland tapirs (*Tapirus terrestris*); photos courtesy of Patricia Medici.

tests on these food items. In group feeding, the proportional consumption of each food item was estimated on the basis of the calculated metabolic body weight of the animals.

Analyses and Calculations

Samples of concentrate feeds, forage, and browse used in the study were sent to Central Laboratories (Central Laboratories, Banbury, Oxon, UK) to determine DM content (as % of wet weight), crude protein (CP% DM), crude ash (CA% DM), neutral detergent fiber (NDF% DM), acid detergent fiber (ADF% DM), and acid detergent lignin (ADL% DM) according to standard methods [Baer et al., 1985]. For the roughages, the following estimates for the content of fat (% DM) were used: browse at 4% DM, grass/lucerne hay at 2% DM, and straw at 2% DM. Hemicellulose was calculated as NDF–ADF and nonstructural carbohydrates (NSC) as 100–CP–fat–CA–NDF. Nutrient values for produce and other foodstuffs were taken from the "Zootrition" (ZOOTRITION^{TM} Version 2.6, Saint Louis Zoo, Bronx, NY) computer program. Diet calculations were performed using standard spreadsheet software. The digestible energy (DE) content of the feeds was estimated using the equation developed for horses by Pagan [1998].

$$\text{DE (kcal/kg DM)} = 2{,}118 + 12.18\ (\text{CP\%}) - 9.37\ (\text{ADF\%}) - 3.83\ (\text{hemicellulose\%}) + 47.18\ (\text{fat\%}) + 20.35\ (\text{NSC\%}) - 26.3\ (\text{ash\%})$$

and converted to joules.

A maintenance energy requirement for mammalian hindgut fermenters (like horses and rhinoceroses) of 0.60 MJ/kg$^{0.75}$/d was assumed [Clauss et al., 2005b]. For diet evaluation, the feeding recommendations of Lintzenich and Ward [1997] for zoo ungulates and feeding guidelines for horses [NRC, 1989; Meyer and Coenen, 2002; Frape, 2004] were used. Differences between the species were tested by independent *t*-test or Mann–Whitney *U*-test and correlations between the BCS or the FS and different parameters of DM and energy intake or diet composition were obtained by correlation analysis using SPSS 16.0 software (SPSS, Chicago, IL). The significance level was set to 0.05.

RESULTS

BCS averaged at 3.4 ± 0.6 (3.8 ± 0.5 for *T. indicus* and 3.1 ± 0.5 for *T. terrestris*, $P = 0.004$), with 2 animals below and 11 animals above 3.0. FS averaged at 3.4 ± 0.8 (3.6 ± 0.5 for *T. indicus* and 3.2 ± 0.9 for *T. terrestris*, $P = 0.149$), with no animal scoring consistently at 2.0 and 14 animals scoring at 3.0 and higher.

Dry matter intake (DMI) ranged from 48 to 86 g/kg$^{0.75}$/d and was significantly higher in *T. indicus* (70 ± 13 g/kg$^{0.75}$/d) than in *T. terrestris* (54 ± 6 g/kg$^{0.75}$/d, $P = 0.001$) (Table 3). Tapirs were observed during the study to rapidly and completely consume pelleted feeds and produce, whereas roughages were only partially consumed. Across the collections, as a percentage of DMI, pelleted feeds, bread, and grains represented the largest portion of the diet with a mean of 46 ± 17%, followed by fruit and vegetables at 26 ± 12%, forages with a mean of 17 ± 11%, and browse with a mean of 11 ± 11% DMI (Table 3). There were no significant differences in diet composition between the species, but the proportion of browse tended to be higher in *T. indicus* (16 ± 16 %) than in *T. terrestris* (8 ± 4 %, $P = 0.057$). No *T. terrestris* ingested a diet with a proportion of roughage (hay and browse) even close to the recommendation of 70% DMI [Lintzenich and Ward, 1997], and only two *T. indicus* did so. The NRC [1989] recommendation of feeding horses at maintenance 100%-roughage diets (whether this is considered suitable for tapirs or not) was evidently not met, and not even the general recommendation for horses by Frape [2004] that roughage should never drop below 50% of the DMI was achieved in more than the afore-mentioned two cases. Meyer and Coenen [2002] recommend a daily minimum of intact roughage of 0.5 kg per 100 kg body mass for horses; this recommendation was met in the two already mentioned and only in two additional cases.

CP (14.4–20% DM) and NDF (34.4–41.1% DM) levels recommended by Lintzenich and Ward [1997] were met by the consumed diets in 5 and 12 cases, respectively. On average, *T. indicus* ingested diets with a significantly higher level of NDF (36.6 ± 9.8% DM) than *T. terrestris* (28.7 ± 6.3% DM, $P = 0.033$). Other differences between the species in dietary nutrient levels were not significant.

With regard to the calculated DE intakes, 2 animals were below and 19 animals above the assumed maintenance requirement, ranging from 0.57 to 0.87 MJ/DE/kg$^{0.75}$/d (Table 3). *T. indicus* ingested significantly more DE (0.79 ± 0.07 MJ/DE/kg$^{0.75}$/d) than *T. terrestris* (0.68 ± 0.10 MJ/DE/kg$^{0.75}$/d, $P = 0.008$).

There was a significant, positive correlation between BCS and FS ($R = 0.51$, $P = 0.017$), indicating that animals tending toward obesity had softer feces. Both BCS ($R = 0.56$, $P = 0.007$) and FS ($R = 0.55$, $P = 0.008$) were positively correlated to the calculated DE intake (Fig. 4a, b). No correlations were found between mean FS and the dietary nutrient or fiber levels. The proportion of fruits and vegetables was highly positively correlated to the overall dietary level of NSC ($R = 0.70$, $P < 0.001$) and negatively correlated to the overall dietary protein level ($R = -0.63$, $P = 0.002$), whereas roughage significantly reduced the overall NSCH ($R = -0.72$, $P < 0.001$) and increased fiber levels (e.g. ADF, $R = 0.85$, $P < 0.001$).

There were no statistical differences regarding the health records of the different species. Among the health problems noted, only colic yielded significant results with respect to other parameters. Animals with colic ($n = 4$) were significantly heavier ($P = 0.020$) and had a higher BCS ($P = 0.015$) than the other animals.

TABLE 3. Body mass (BM), dry matter intake (DMI), body condition score (BCS), feces score (FS), the composition of the ingested diet in terms of ingredients and nutrients (crude protein—CP, crude ash—CA, neutral detergent fiber—NDF, acid detergent fiber—ADF), digestible energy intake (DEI), and health records (L, lameness; D, diarrhea; V, vomitus; C, colic) of the captive tapirs investigated in this study

Species	Zoo	BM (kg)	DMI (g/kg$^{0.75}$/d)	BCS	FS	Fruits/veg. (% DMI)	Pellets/grains/bread (% DMI)	Roughage (% DMI)	Browse (% DMI)	CP (% DM)	Fat (% DM)	CA (% DM)	NDF (% DM)	ADF (% DM)	DEI[a] (MJ/kg$^{0.75}$/d)	Health record
T. indicus	A	369[b]	79	4.0	4.33	12	78	5	5	11.1	2.9	8.6	40.4	22.5	0.87	L
T. indicus	A	380[b]	79	4.0	4.17	12	79	5	4	11.1	2.9	8.6	40.2	22.2	0.87	L, D, V, C
T. indicus	C	326[b]	86	4.0	4.08	15	15	32	38	16.7	2.9	7.9	47.8	34.8	0.85	L, D
T. indicus	C	425[b]	81	4.5	4.08	13	13	34	41	16.9	2.9	7.9	49.2	36.1	0.79	D, V, C
T. indicus	D	310	55	3.0	3.33	37	38	1	24	12.6	3.7	5.4	23.2	15.5	0.75	L
T. indicus	D	350	55	4.0	3.33	37	38	1	24	12.6	3.7	5.4	23.2	15.5	0.75	C
T. indicus	G	380[b]	71	4.0	3.38	29	43	25	3	12.5	2.6	7.2	39.0	20.2	0.81	L
T. indicus	G	93[b]	71	3.0	3.38	29	43	25	3	12.5	2.6	7.2	39.0	20.2	0.81	–
T. indicus	G	353[b]	51	3.5	2.75	41	46	8	5	12.4	2.7	6.8	27.1	14.4	0.65	–
mean T. indicus		332±96	70±13	3.8±0.5	3.65±0.53	25±12	44±23	15±14	16±16	13.2±2.2	3.0±0.4	7.2±1.2	36.6±9.8	22.4±8.0	0.79±0.07	
T. terrestris	B	255	50	3.5	3.00	13	54	28	5	16.9	3.4	8.0	29.6	20.3	0.60	–
T. terrestris	B	230	47	3.0	2.83	12	61	22	5	16.4	3.6	8.0	28.7	18.9	0.57	–
T. terrestris	B	200	47	2.0	2.83	12	61	22	5	16.4	3.6	8.0	28.7	18.9	0.57	L
T. terrestris	D	230	60	3.0	2.63	33	49	5	13	12.8	3.8	5.4	21.0	12.9	0.83	–
T. terrestris	D	240	60	3.0	2.63	33	49	5	13	12.8	3.8	5.4	21.0	12.9	0.83	L
T. terrestris	D	275	56	4.0	4.67	32	54	6	8	12.9	3.8	5.5	19.8	11.8	0.78	–
T. terrestris	D	225	56	3.0	4.67	32	54	6	8	12.9	3.8	5.5	19.8	11.8	0.78	L

TABLE 3. Continued

Species	Zoo	BM (kg)	DMI (g/ $kg^{0.75}$/ d)	BCS	FS	Fruits/ veg. (% DMI)	Pellets/ grains/ bread (% DMI)	Roughage (% DMI)	Browse (% DMI)	CP (% DM)	Fat (% DM)	CA (% DM)	NDF (% DM)	ADF (% DM)	DEI[a] (MJ/ $kg^{0.75}$/ d)	Health record
T. terrestris	E	260	67	3.5	3.33	15	46	27	12	11.1	3.2	7.8	38.2	22.7	0.77	L, C
T. terrestris	E	235	54	3.0	3.88	17	52	20	11	11.4	3.3	7.6	33.3	19.7	0.65	L
T. terrestris	E	230	54	3.0	3.88	17	52	20	11	11.4	3.3	7.6	33.3	19.7	0.65	L, D
T. terrestris	F	225	49	3.5	2.25	45	30	22	3	7.4	2.6	5.2	33.3	19.9	0.62	–
T. terrestris	F	210	49	2.5	2.25	45	30	22	3	7.4	2.6	5.2	33.3	19.9	0.62	L, V
T. terrestris	F	235	49	3.0	2.25	45	30	22	3	7.4	2.6	5.2	33.3	19.9	0.62	L, D, V
Mean *T. terrestris*		235±20	54±6	3.1±0.5	3.16±0.86	27±13	48±11	17±9	8±4	12.1±3.3	3.3±0.5	6.5 ±1.3	28.7±6.3	17.6±3.8	0.68±0.10	
Mean all tapirs		274±78	60±12	3.4±0.6	3.36±0.77	26±12	46±17	17±11	11±11	12.5±2.9	3.2±0.5	6.8±1.3	31.9±8.7	19.6±6.2	0.73±0.10	

[a]Calculated according to Pagan (1998).
[b]Body mass measured by weighing.

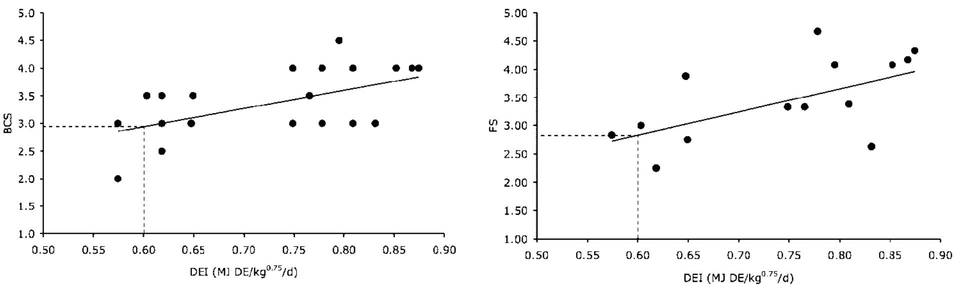

Fig. 4. Correlation of the calculated digestible energy (DE) intake and (**a**) the body condition score (BCS) and (**b**) the mean feces score (FS) in captive tapirs. DE calculated according to the equation by Pagan [1998] for domestic horses. Note that "normal" BCS (BCS 3) is, by extrapolation, achieved at the assumed maintenance DE level; "normal" FS (FS 1–2) is not observed and not reached by extrapolation.

DISCUSSION

The results of this survey indicate a population that tends toward obesity, with softer feces than usual for the species, high DE intakes, and diets that lack roughage, either as dried forages or browse. The correlations found in the data support the common sense concept that high–energy diets are linked to obesity and soft stools. In particular, the blatant lack of fiber in the diets ingested by the animals is striking and can be linked to the high use of fruits, vegetables, pellets, grains, and bread, which is in direct contrast to current feeding recommendations [Oftedal et al., 1996; Lintzenich and Ward, 1997]. Although this study could not test for, or elucidate reasons for, a potential general reluctance of tapirs to ingest commonly offered roughages such as grass hay, the results suggest that many current tapir feeding regimes do not try to achieve a high roughage intake but rely on other food items of known high acceptance instead, irrespective of the possible health implications. This approach may be heightened by the apparent reluctance of the tapirs to consume the usually fed forages.

Overfeeding and obesity are common problems mentioned in the literature on zoo animal nutrition [Ange et al., 2001; Schwitzer and Kaumanns, 2001; Clauss and Hatt, 2006; Hatt and Clauss, 2006]; in herbivores, the problem is generally linked to a diet that comprises low proportions of high-fiber feeds and that exceeds the caloric requirement of the species. In the tapirs of this study, BCSs that were believed to be ideal were reached at calculated DE intakes of 0.6 MJ/DE/kg$^{0.75}$/d (Fig. 4a). As this is the assumed maintenance energy requirement for hindgut fermenting herbivores, this result supports the concept that tapirs fed at this maintenance level should not become obese. As an aside, it should be noted that this result does not corroborate the absolute value of 0.6 MJ/DE/kg$^{0.75}$/d as the maintenance requirement for tapirs. The absolute value is derived from the calculation based on digestibility trials with domestic horses. Although the digestive efficiency of horses is similar to some other large hindgut fermenters, such as the white rhinoceroses (*Ceratotherium simum*) [Kiefer, 2002] and Indian rhinoceroses (*Rhinoceros unicornis*) [Clauss et al., 2005a], it was demonstrated that the horse is not an adequate model for digestion in elephants [Clauss et al., 2003] or black rhinoceroses (*Diceros bicornis*) [Clauss et al., 2006]. As browsers, tapirs could be expected to actually achieve lower digestion coefficients on comparable diets than horses. Thus, if a diet of 0.6 MJ/DE/kg$^{0.75}$/d, calculated on the basis of horse digestion trials, provided the maintenance requirement for tapirs (preventing both weight loss and obesity), then the real energy requirements of tapir might be even lower than that of the horse. Indeed, Foose [1982] found lower digestive efficiencies in tapirs as compared with wild equids on similar forages. However, until more data on the digestive efficiency of tapirs are available, this question remains unresolved, yet it may be of more academic than practical interest. With regard to herbivores, offering food at a precise maintenance level is virtually impossible; however, if the major proportion of the diet offered consists of roughages or other high-fiber ingredients, an excessive energy intake is less likely, even if theoretically possible. Ideally, body weight should be monitored in tapirs, as with other animals, on a regular basis. If this is not possible, regular body condition scoring by experienced personnel that does not have everyday contact with the animals is a good alternative, providing a safeguard to ensure the animals are managed so that they do not gradually become overweight or, conversely, emaciated.

Given the consistency of feces from tapirs in the wild (Fig. 3), an FS of 1 or 2 appears ideal for tapirs. Across the animals of this study, such an FS was not attained consistently, not even by animals fed at assumed maintenance (Fig. 4b). Rather, even at the assumed maintenance feeding level, FS of 3 were observed and extrapolated by regression from the whole data set. This indicates that the DE should be delivered by a different diet composition than that offered at the present moment. No significant correlations were found between the mean FS and the dietary nutrient composition (nutrients in % DM), the ingredient composition of the diet (roughages in % DM), nor with the dietary water intake. Our results, therefore, do not concur with the findings of Nijboer et al. [2006a,b] where dietary parameters were reported as a decisive factor in determining the fecal consistency in captive colobines. In the Javan langur (*Trachypithecus auratus*), a firmer fecal consistency was correlated to both an increase in NDF and a decrease in dietary water [Nijboer et al., 2006b]. Our findings do not confirm such a case in the captive tapir, and we can therefore not extrapolate recommendations for improved fecal consistency in captivity from this study alone. Anecdotal evidence from Zurich Zoo does indicate that a diet change from a produce- and bread-dominated diet to a diet dominated by alfalfa hay resulted in a change of feces consistency that would correspond to FS of 5 (before) and 2 (after the diet change) [Clauss et al., 2008b].

One interesting question is whether the data collected in the course of this survey allow any conclusions as to the suitability of the roughage source used. In the two zoos where the highest average proportion of hay roughage in total DMI was achieved (zoos B and C in Table 3), alfalfa hay was used (in % DM: B—CP 24.1, NDF 45.2; C—CP 17.7 %, NDF 59.7). Nearly similar proportional hay intakes were observed at zoos E, F, and G on grass hay (in % DM: CP 7.6–10.2, NDF 81.2–82.0, ADF 41.3–45.3, ADL 6.0–7.1), in contrast to low hay intakes of grass hay (in % DM: CP 9.4–12.7, NDF 74.1–79.1, ADF 39.4–39.7, ADL 6.4–7.3) at zoos A and D. These observations confirm the observation also noted by Foose [1982] that tapirs might not accept grass hay readily. Clearly, intake studies with tapirs on forage-only diets of varying quality and botanical composition are warranted.

Besides predisposing for obesity and soft feces, captive diets such as those documented in our study could also render tapirs vulnerable to other health problems. Although the statistical result that indicates a higher risk for colic in obese tapirs should not be overemphasized, colic and obstipation are indeed important problems observed in captive tapirs [Janssen, 2003]. In horses, a high intake of roughage that is both of a high hygienic standard and with a low proportion of unwieldy, woody components is considered beneficial for the prophylaxis for colic or obstipation [Meyer and Coenen, 2002]. As such a diet would also bear a lower risk for obesity, the association found in our study population appears logical, even if not compelling owing to the low sample size.

In captive Malayan and Brazilian tapirs, several reports have been published regarding dental disease and oropharygneal abscessation [Janssen et al., 1999; Mangart Søland et al., 2008]. This condition makes dental extraction a frequent medical intervention in captive animals. A possible contributory factor for the dental disease may be the high level of sugars and starch in the diets that specifically include large amounts of fruits and grain products. Furthermore, the high fruit intake may result in elevated vitamin C intake, which is likely to enhance iron absorption from the gut [Ballot et al., 1987; Fleming et al., 2002]. Tapirs have been shown to be susceptible to iron storage disease [Paglia et al., 2000]; at the Philadelphia Zoological Garden, 12 out of 19 postmortem cases investigated histologically between 1902 and 1994 were found to have hemosiderosis [Bonar et al., 2006]. This condition has been reported to affect Baird's tapirs (*T. bairdii*), Malayan tapirs, and lowland tapirs and may be fatal. Therefore, it is recommended that the uptake of excessive iron and/or intake of iron absorption enhancers should be avoided. Additionally, obesity in general contributes to the frequent occurrence of pad and sole ulcerations, which may be of particular relevance when keeping animals on hard substrate [Janssen et al., 1999]. In conclusion, adapting the diet of captive tapirs in accordance with current feeding recommendations for both forage-feeding of zoo herbivores and for un-worked domestic horses, i.e. forage-dominated diets, could prove to be an important prophylactic health measure in the captive management of the species.

CONCLUSIONS

1. In a survey on the feeding of captive tapirs in UK zoological collections, diets ingested by the study population were dominated by pelleted feeds, grains, bread, and commercial produce (fruits and vegetables), and contained comparatively low proportions of forages or browse. The proportion of roughage feeds was distinctively lower than recommended for these species or for maintenance feeding of domestic horses.
2. The application of a body condition score (BCS) and a fecal score (FS) revealed that the study population showed a tendency toward obesity, and toward softer fecal consistency than free-ranging animals.
3. BCS and FS were correlated to the calculated digestible energy (DE) intake, suggesting that the trends of obesity and soft stools in this population were linked to the provision of excessive DE.
4. It is suggested that following feeding recommendations for captive tapirs or domestic horses at maintenance (i.e. increasing the proportion of roughages and/or browse in the current diets) represent a logical measure with a prophylactic potential against reported health problems in captive tapirs.

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REFERENCES

Aldan EC, Sanchez SG, Hernandez CC, Andrade DMG. 2004. Foraging habits and diet of *Tapirus bairdii* in the Sierra Madre of Chiapas, Mexico. Second International Tapir Symposium. Panama City, Panama. p 35.

Ange K, Crissey SD, Doyle C, Lance K, Hintz H. 2001. A survey of African and Asian elephant diets and measured body dimensions compared to their estimated nutrient requirements. Proc Conf AZA Nutr Advis Group 4:5–14.

Baer DJ, Oftedal OT, Fahey GC. 1985. Feed selection and digestibility by captive giraffe. Zoo Biol 4:57–64.

Ballot D, Baynes RD, Bothwell TH, Gillooly M, MacFarlane BJ, MacPhasil AP, Lyons G, Derman DP, Bezwoda WR, Torrance JD, Bothwell JE, Mayet F. 1987. The effects of fruit juices on the absorption of iron from a rice meal. Br J Nutr 57:331–343.

Bodmer RE. 1990. Fruit patch size and frugivory in the lowland tapir (*Tapirus terrestris*). J Zool (Lond) 222:121–128.

Bonar CJ, Trupkiewicz JG, Toddes B, Lewandowski AH. 2006. Iron storage disease in tapirs. J Zoo Wildl Med 37:49–52.

Clauss M, Dierenfeld ES. 2008. The nutrition of browsers. In: Fowler ME, Miller RE, editors. Zoo and wild animal medicine: current therapy 6. St. Louis: Saunders Elsevier. p 444–454.

Clauss M, Hatt JM. 2006. The feeding of rhinoceros in captivity. Int Zoo Yb 40:197–209.

Clauss M, Löhlein W, Kienzle E, Wiesner H. 2003. Studies on feed digestibilities in captive Asian elephants (*Elephas maximus*). J Anim Physiol Anim Nutr 87:160–173.

Clauss M, Polster C, Kienzle E, Wiesner H, Baumgartner K, von Houwald F, Ortmann S, Streich WJ, Dierenfeld ES. 2005a. Studies on digestive physiology and feed digestibilities in captive Indian rhinoceros (*Rhinoceros unicornis*). J Anim Physiol Anim Nutr 89:229–237.

Clauss M, Polster C, Kienzle E, Wiesner H, Baumgartner K, von Houwald F, Streich W, Dierenfeld E. 2005b. Energy and mineral nutrition and water intake in the captive Indian rhinoceros (*Rhinoceros unicornis*). Zoo Biol 24:1–14.

Clauss M, Castell JC, Kienzle E, Dierenfeld ES, Flach EJ, Behlert O, Ortmann S, Streich WJ, Hummel J, Hatt JM. 2006. Digestion coefficients achieved by the black rhinoceros (*Diceros bicornis*), a large browsing hindgut fermenter. J Anim Physiol Anim Nutr 90:325–334.

Clauss M, Kaiser T, Hummel J. 2008a. The morphophysiological adaptations of browsing and grazing mammals. In: Gordon IJ, Prins HHT, editors. The ecology of browsing and grazing. Heidelberg: Springer. p 47–88.

Clauss M, Aufranc R, Hatt JM. 2008b. Fütterung und Kotkonsistenz von Flachlandtapiren (*Tapirus terrestris*) im Zürich Zoo (Feeding and fecal consistency of lowland tapirs at Zurich Zoo). Zool Garten NF 77:297–302.

Diz MJO. 2006. The diet of captive lowland tapirs (*Tapirus terrestris*) in Argentina. Third International Tapir Symposium. Buenos Aires, Argentina. p 30–31.

Downer CC. 2001. Observations on the diet and habitat of the mountain tapir (*Tapirus pinchaque*). J Zool (Lond) 254:279–291.

Fleming DJ, Tucker KL, Jacques PF, Dallal GE, Wilson PWF, Wood RJ. 2002. Dietary factors associated with the risk of high iron stores in the elderly Framingham Heart study cohort. Am J Clin Nutr 76:1375–1384.

Foose TJ. 1982. Trophic strategies of ruminant versus nonruminant ungulates. [PhD thesis]. Chicago, University of Chicago.

Frape D. 2004. Equine nutrition and feeding, 3rd ed. London: Blackwell Publishing.

Galetti M, Keuroghlian A, Hanada L, Morato MI. 2001. Frugivory and seed dispersal by the lowland tapir (*Tapirus terrestris*) in Southeast Brazil. Biotropica 33:723–726.

Hatt JM, Clauss M. 2006. Feeding Asian and African elephants (*Elephas maximus* and *Loxodonta africana*) in captivity. Int Zoo Yb 40:88–95.

Henry O, Feer F, Sabatier D. 2000. Diet of the lowland tapir (*Tapirus terrestris*) in French Guiana. Biotropica 32:364–368.

Hummel J, Fritz J, Kienzle E, Medici EP, Lang S, Zimmermann W, Streich WJ, Clauss M. 2008. Differences in fecal particle size between free-ranging and captive individuals of two browser species. Zoo Biol 27:70–77.

Janssen DL. 2003. Tapiridae. In: Fowler ME, Miller RE, editors. Zoo and wild animal medicine, 5th ed. St. Louis: Saunders Elsevier.

Janssen DL, Rideout BA, Edwards MS. 1999. Tapir medicine. In: Fowler ME, Miller RE, editors. Zoo and wild animal medicine: current therapy IV. Philadelphia, PA: WB Saunders. p 562–568.

Kiefer B. 2002. Qualität und Verdaulichkeit der vom Breitmaulnashorn aufgenommenen Nahrung. [Dissertation]. München, LMU München.

Lang S, Medici E, Fritz J, Hatt J, Hummel J, Clauss M. 2005. Faeces consistency in captive tapirs. Abstr Book Eur Zoo Nutr Meet 4:38.

Lintzenich BA, Ward AM. 1997. Hay and pellet ratios: considerations in feeding ungulates. Nutrition Advisory Group Handbook Fact Sheet 006.

Mahler AE. 1984. Activity budgets and use of exhibit space by South American tapir (*Tapirus terrestris*) in a zoological park setting. Zoo Biol 3:35–46.

Mangart Søland T, Grøndahl C, Bertelsen MF. 2008. Oral dental extraction in two Malayan tapirs (*Tapirus indicus*). Proc Sci Meet Eur Assoc Zoo Wildl Vet 7:261–262.

Meyer H, Coenen M. 2002. Pferdefütterung. Berlin: Parey Verlag.

Naranjo EJ. 1995. Habitos de alimentatión del tapir (*Tapirus bairdii*) en un bosque tropical húmedo de Costa Rica. Vida Silvana Neotrop 4:32–37.

National Research Council. 1989. Nutrient requirements of horses. 5th ed. Washington, DC: National Academy Press.

Nijboer J, Clauss M, Everts H, Beynen AC. 2006a. Effect of dietary fibre on the faeces score in colobine monkeys at Dutch Zoos. In: Fidgett A, Clauss M, Eulenberger K, Hatt JM, Hume I, Janssens G, Nijboer J, editors. Zoo animal nutrition, Vol. III. Fürth: Filander. p 145–155.

Nijboer J, Clauss M, Olsthoorn M, Noordermeer W, Huisman TR, Verheyen C, van der Kuilen J, Streich WJ, Beynen AC. 2006b. Effect of diet on the feces quality in Javan langur (*Trachypithecus auratus auratus*). J Zoo Wildl Med 37:366–372.

Oftedal OT, Allen ME. 1996. The feeding and nutrition of omnivores with emphasis on primates. In: Kleiman DG, Allen ME, Thompson KV, Lumpkin S, editors. Wild mammals in captivity principles and techniques. Chicago: University of Chicago Press. p 148–157.

Oftedal OT, Baer DJ, Allen ME. 1996. The feeding and nutrition of herbivores. In: Kleiman DG, Allen ME, Thompson KV, Lumpkin S, editors. Wild mammals in captivity principles and techniques. Chicago: University of Chicago Press. p 129–138.

Pagan JD. 1998. Measuring the digestible energy content of horse feeds. In: Pagan JD, editor. Advances in equine nutrition. Nottingham, UK: Nottingham University Press. p 71–76.

Paglia DE, Miller CL, Foerster SH, Wynne JE, Tsu ICH, Kenny DE. 2000. Evidence for acquired iron overload in captive tapirs. Proc Am Assoc Zoo Vet. p 124–126.

Salas LA, Fuller TK. 1996. Diet of the lowland tapir (*Tapirus terrestris*) in the Tabaro River valley, southern Venezuela. Can J Zool 74:1444–1451.

Schmidt DA, Kerley MS, Porter JH, Dempsey JL. 2005. Structural and nonstructural carbohydrate, fat, and protein composition of commercially available, whole produce. Zoo Biol 24:359–373.

Schwitzer C, Kaumanns W. 2001. Body weights of ruffed lemurs (*Varecia variegata*) in European zoos with reference to the problem of obesity. Zoo Biol 20:261–269.

Terwilliger VJ. 1978. Natural history of Baird's tapir on Barro Colorado Island, Panama Canal zone. Biotropica 10:211–220.

Tobler MW. 2002. Habitat use and diet of Baird's tapirs (*Tapirus bairdii*) in a montane cloud forest of the Cordillera de Talamanca, Costa Rica. Biotropica 34:468–474.

Torres IL, Pinera EJN, Andrade DMG. 2004. Diet and food habits of Baird's Tapir in a cloud forest of Southeastern Mexico. Second International Tapir Symposium. Panama City, Panama. p 36.

Williams KK, Petrides GA. 1980. Browse use, feeding behaviour and management of the Malayan tapir. J Wildl Manag 44:489–494.

Wilson RA, Wilson S. 1973. Diet of captive tapirs. Int Zoo Yb 13:213–217.