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Mineral absorption in tapirs (Tapirus spp.) as compared to the domestic horse — Source link

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Abstract

In order to test whether mineral recommendations for horses are likely to guarantee adequate mineral provision for tapirs (Tapirus spp.), we investigated the apparent absorption (aA) of macro- and microminerals in 18 tapirs from 5 zoological institutions in a total of 24 feeding trials with total faecal collection. Feeds and faeces were analysed for Ca, P, Mg, Na, K, Fe, Cu, and Zn. The resulting aA coefficients, and the linear relationships of apparently absorbable dietary mineral content to total dietary mineral content (per 100g dry matter), were compared to data for domestic horses. While there were no apparent differences in the absorption patterns for P, K, Na, K, Fe, Cu or Zn, both Ca and Mg absorption were distinctively higher in tapirs than in horses. Tapirs are browsers that are adaptaed to a diet of higher Ca content and higher Ca:P ratio than equids, and high absorptive efficiency for Ca might have evolved to ensure that high dietary Ca concentrations to not bind dietary P in the intestine and thus make it unavailable for hindgut microbes. Like in other hindgut fermenters, absorption coefficients for Ca increased with dietary Ca:P ratio, and urinary Ca:creatinine ratios increased with dietary Ca. Several zoo diets used were deficient in one or more minerals. When compared to faeces from free-ranging animals, faeces from zoo animals had higher concentrations of most minerals, probably indicating a lesser diluting effect of indgestible fibre in zoo animals.

Mineral absorption in tapirs (*Tapirus spp.*) as compared to the domestic horse

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Running title: Minerals in tapirs

Summary

In order to test whether mineral recommendations for horses are likely to guarantee adequate mineral provision for tapirs (*Tapirus spp.*), we investigated the apparent absorption (aA) of macro- and microminerals in 18 tapirs from 5 zoological institutions in a total of 24 feeding trials with total faecal collection. Feeds and faeces were analysed for Ca, P, Mg, Na, K, Fe, Cu, and Zn. The resulting aA coefficients, and the linear relationships of apparently absorbable dietary mineral content to total dietary mineral content (per 100g dry matter), were compared to data for domestic horses. While there were no apparent differences in the absorption patterns for P, K, Na, K, Fe, Cu or Zn, both Ca and Mg absorption were distinctively higher in tapirs than in horses. Tapirs are browsers that are adaptaed to a diet of higher Ca content and higher Ca:P ratio than equids, and high absorptive efficiency for Ca might have evolved to ensure that high dietary Ca concentrations to not bind dietary P in the intestine and thus make it unavailable for hindgut microbes. Like in other hindgut fermenters, absorption coefficients for Ca increased with dietary Ca:P ratio, and urinary Ca:creatinine ratios increased with dietary Ca. Several zoo diets used were deficient in one or more minerals. When compared to faeces from free-ranging animals, faeces from zoo animals had higher concentrations of most minerals, probably indicating a lesser diluting effect of indgestible fibre in zoo animals.

Key words: tapir, *Tapirus indicus*, *Tapirus terrestris*, horse, *Equus caballus*, sodium, potassium, magnesium, calcium, phosphorus, iron, copper, zinc, absorption

Introduction

The mineral status of zoo herbivores is of particular interest (e.g. Dierenfeld et al. 2005). On the one hand, excessive use of pelleted feeds or mineral supplements can lead to intakes far higher than recommended (e.g. Clauss et al. 2007); on the other hand, if no supplementation occurs, especially diets based on roughages, grains and produce can be deficient in several minerals (Ange et al. 2001; Schwarm et al. 2004; Clauss et al. 2005). Actually, current feeding guidelines for large herbivores recommend the use of roughage-based diets supplemented with a moderate proportion of complete, pelleted feeds in order to prevent such deficiencies (Lintzenich and Ward 1997). However, in particular in the case of tapirs (*Tapirus spp.*), these guidelines appear to be rarely followed (Wilson and Wilson 1973; Clauss et al. 2008; Wilkins et al. 2008).

When assessing herbivore diets for their suitability in terms of mineral content, usually requirements are extrapolated from either domestic ruminants or horses (Oftedal et al. 1996). Tapirs are hindgut fermenters with a digestive anatomy similar to that of horses (Mitchell 1903-6), but with a dentition apparently more adapted (Hummel et al. 2008) to their natural diet – browse (Terwilliger 1978; Williams and Petrides 1980; Naranjo 1995; Salas and Fuller 1996; Henry et al. 2000; Downer 2001; Tobler 2002). Browsers may differ from grazers in terms of digestive efficiency (Pérez-Barbería et al. 2004; Clauss et al. 2006a), which might also influence mineral absorption (Clauss et al. 2007).

Therefore, we wanted to generate data on the absorption of minerals in captive tapirs, in order to facilitate a comparison with published data for domestic horses, to test whether differences in mineral absorption could be detected that would both have ecological relevance and necessitate a differentiated mineral supplementation regime for captive tapirs. At the same time, this study allowed a general evaluation of the mineral supplementation of currently used diets for captive tapirs.

Methods

The principal setup of this study was similar to that used in rhinoceros (Clauss et al. 2005; Clauss et al. 2007). Feeding trials were performed with 13 lowland tapirs (*Tapirus terrestris*) and 5 Malayan tapirs (*Tapirus indicus*) from five zoological institutions (Table 1). Three animals were between 1-3 years old; the others were adult. All animals were not reproducing. Animals were kept individually,

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food intake was recorded by weighing offered feeds and leftovers for 7 days, and faecal excretion by total collection for 5 days. Whenever urination on an uncontaminated surface was observed directly, and access to the urine was possible, fresh urine was sampled by the use of a disposable pipette, taking care to include all urinary fractions. One or two different rations were used: the diets usually fed at the respective zoos consisted of varying proportions of roughage, fruits, vegetables and concentrates (Table 1); in six animals, additionally roughage-only diet was fed in a second trial (total number of feeding trials = 24). For the diets usually fed at the zoos, no particular adaptation period was considered necessary. For the roughage-only diets, the adaptation period was 7 days; a longer adaptation period would have been desirable, but would have excluded the collaboration of most zoological facilities. During the study period, the animals did not have access to mineral licks. A detailed description of all diets used in this study is given in Lang-Deuerling (2008).

To obtain representative faecal samples, the outer layer of dung balls or dung heaps was removed to avoid contamination of the sample. The rest of the material was thoroughly mixed, and a subsample representing 10 % of the whole sample was taken and frozen at –20 °C. After thawing, all faecal samples were pooled per animal and feeding period. Representative samples of feeds and the pooled faecal samples were analysed for mineral content (Ca, P, Mg, Na, K, Fe, Cu, Zn). All analyses were run in duplicate. To 0.5 g of sample, 5 ml of 65% HNO_3 was added for wet ashing (1200 mega High Performance Microwave, MLS, Milestone, Leutkirch, Germany). Ca, Na and K were analysed by flame photometry (EFOX 5053, Eppendorf, Hamburg, Germany), P by spectrophotometry (using ammonium molybdic acid and ammonium vanadic acid, 1:1; GENESYS 10 UV, Thermo Spectronic, Dreieich, Germany), and Cu, Fe and Zn by atomic absorption spectroscopy (AAnalyst 800, Perkin-Elmer, Waltham, MA, USA).

Urine samples were pooled per individual and trial period; Ca content was determined as described above after intensive stirring to obtain a homogenous sample (due to the high proportion of particulate calcium, tapir urine tends to divide into a sediment and a fluid phase immediately), and creatinine was measured using a test kit (Metra Biosystems, Mountain View, CA) and photometry.

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For comparison, six individual faecal samples from free-ranging *T. terrestris* from Brazil and the sotmach contents of one accidentally killed *T. terrestris* from the wild were available. These samples were sent frozen from Brazil and submitted to the same analyses.

Apparent absorption (aA) of minerals was calculated using the formula aA [%]= (mineral ingested [g] – mineral excreted [g]) / mineral ingested [g] * 100. Mineral content was plotted against absorbable mineral content in 100 g DM. Differences in the resulting regressions to those derived from literature data on domestic horses (for a complete reference list, see Clauss et al. 2007) as well as of calculated mean aA coefficients were tested by analysis of covariance and U-test, respectively, using the SPSS 16.0.1 statistical package (SPSS Inc., Chicago, Illinois, USA). In these regressions, the regression slope (a) corresponds to the 'true' absorption coefficient, and the negative intercept (b) to the endogenous fecal losses (EFL) (Robbins 1993). The significance level was set at 0.05.

Results

Dietary mineral contents, aA coefficients and the regression equations are summarized in Table 2; the respective data plots are depicted in Figure 1. Mean aA coefficients differed significantly between the species for the macrominerals Ca, P, Mg, and K but not for Na; they also differed for Cu, but not for the other two microminerals.

The slopes of the regression lines (Fig. 1) differed significantly between tapirs and horses for all minerals investigated; therefore, differences in the intercept (EFL) could not be evaluated. In spite of statistical differences in slope, the data scatter appeared similar between horse and tapir for P, Na, K, Fe, Cu, and Zn; for Ca and Mg, however, the consistently higher proportion of digestible mineral in the diet appeared systematic (Fig. 1).

The dietary Ca:P ratio was positively correlated to the aA of Ca ($R=0.67$, $p<0.001$), and negatively correlated to the aA of P ($R=-0.45$, $p=0.027$) (Fig. 2). Urine could be collected in 9 feeding trials (7 animals). The Ca:Creatinine ratio in the urine samples showed a trend for positive correlation to the dietary Ca content (Pearson's $R=0.66$, $p=0.053$) (Fig. 3).

Given the range of mineral content in the regularly used tapir diets, several diets would be considered deficient one or several minerals, with the exception of P, Mg, K and Fe, which were

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always above the recommended minimum (Table 2). The Ca:P ratio of the zoo diets was always lower than the one observed in free-ranging tapirs. The faeces of captive tapirs generally had higher mineral concentrations than faeces of free-ranging tapirs (Table 3); notable exceptions from this pattern were Fe concentrations, and Ca, Na and Cu on the roughage-only diets.

Discussion

Similar to our study on black rhinoceros (Clauss et al. 2007), the results of this study demonstrate that although macromineral absorption is broadly similar between species of similar digestive anatomy, differences do exist. As in the earlier study, absorption coefficients for macrominerals are likely to reflect physiological regularities; for trace minerals, animal mineral status and contaminations of diets and faeces will more seriously influence the results (Robbins 1993). The uniformity of several results, even across the different facilities and species, such as those for Ca or Na (Fig. 1), support the interpretation of the results as species-specific characteristics. With respect to the statistical significance found in most comparisons, the physiological relevance of this difference should be assessed by the magnitude of the difference and a visual inspection of the scatter plots.

The maybe most impressive result from Table 2 is the nearly exact match of the regression equation of digestible dietary Ca versus overall dietary Ca in tapirs to that found in black rhinoceros (Clauss et al. 2007). Bascially all hindgut-fermenting herbivores that have been investigated so far, like elephants, rhinoceroses, equids, rabbits and rodents, and even herbivorous tortoises have higher apparent absorption coefficients for Ca than ruminants or omnivorous and carnivorous mammals, and subsequently excrete the surplus of absorbed Ca in their urine (Cheeke and Amberg 1973; Hintz et al. 1976; Leon and Belonje 1979; Schryver et al. 1983; Kamphues et al. 1986; Shore et al. 1992; Liesegang et al. 2001; Clauss et al. 2003; Clauss et al. 2005), similar to the tapirs in our study (Fig. 3). As in tapirs (Fig. 2), the Ca absorption coefficient increases with an increasing dietary Ca:P-ratio in horses (Schryver et al. 1970; Schryver et al. 1971), elephants (Clauss et al. 2003), and rhinoceroses (Clauss et al. 2005; Clauss et al. 2007). It has been speculated that this could represent an adaptation to hindgut fermentation, namely to prevent the formation of insoluble Ca-P-complexes that could make P unavailable for the hindgut microflora (Clauss et al. 2007). Both black rhinoceroses and tapirs evolved to feed on natural diets of a higher Ca content and higher Ca:P ratio than the natural diets of equids, for example (Table 3). Therefore, if these species need to bypass Ca, their evolved absorption efficiencies should be even higher in order to achieve the same degree of Ca-free ingesta as equids; evidently, this seems to be the case. Because absorption mechanisms for Mg are similar to those for Ca in hindgut fermenters and ruminants (Hintz and Schryver 1973; Reinhardt et al. 1988), the generally higher Mg absorption efficiency fits the pattern.

In contrast to the black rhinoceros, the tapir does not show a relevant difference in the pattern of Na absorption when compared to the domestic horse (Fig. 1). This result indicates that the particularity found in black rhinoceroses should not be automatically assumed to apply to other browsing species. The calculated ‘true’ absorption coefficient for Na of 100 % (Table 2) in tapirs corresponds to the assumed complete Na absorption in mammals in general (Robbins 1993), and the calculated endogenous faecal losses are similar to those of horses. Similar to Na, there were no evident differences between the species in the absorption of the other minerals investigated except those mentioned for Ca and Mg.

Similar to other free-ranging herbivores, tapris use natural mineral licks (Lizcano and Cavelier 2000; Montenegro 2004), the soil of which contains particularly high concentrations of Na, Ca, Mg, P and Cu (Montenegro 2004). The ingestion of such soils is also reflected in the occurrence of soil faeces of free-ranging tapirs (Montenegro 2004) and respective high Fe concentrations (Table 4). Given the low concentrations of Na, P, Cu and Zn in some food plants of free-ranging tapirs when compared to horse requirements (Table 3), such soil ingestion could compensate for these dietary deficiencies. In captive animals, one can assume that the use of salt licks could compensate for a lack of Na in the offered diet; however, deficiencies in other minerals should be avoided by offering a balanced ration.

Similar to black rhinoceroses (Dierenfeld et al. 2005), captive tapirs have been reported to be susceptible to iron storage disease (Paglia et al. 2000; Bonar et al. 2006). In contrast to black rhinoceros (Clauss et al. 2007), however, the diets fed to captive tapirs do not contain particularly excessive amounts of Fe but are within the range measured in the diet of free-ranging animals (Table

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3). One possible explanation for this difference could be the lower proportion of pelleted compound feeds used the tapirs of this study, because compound feeds often contain high levels of Fe (Clauss et al. 2006b). If it is assumed that the diets fed to the tapirs of this study are representative for the feeding of tapirs in Europe (cf. Clauss et al. 2008; Wilkins et al. 2008), and tapirs in North America are rather fed according to the guidelines of Lintzenich and Ward (1997), then it could be predicted that measurements of iron storage disease should be higher in North America due to the higher use of pelleted feeds; this hypothesis, however, remains to be tested.

This hypothetical comparison should not imply that the diets apparently currently fed in Europe are ideal. Actually, diets fed in Europe seem to be surprisingly low in fibre, resulting in faecal consistencies that do not resemble those of free-ranging tapirs (Lang et al. 2005; Clauss et al. 2008; Wilkins et al. 2008). A comparison of the faeces of free-ranging and captive tapirs (Table 4) shows that faeces from captive animals have higher concentrations of most minerals in spite of dietary mineral contents in the range of the stomach contents of a free-ranging tapir (Table 3). This discrepancy is most parsimoniously explained by the dilution effect of undigested fibre in the free-ranging animals, and a presumed lack of fibre in the diet of the captive animals. Correspondingly, mineral concentrations are generally lower in the faeces of tapirs fed roughage-only diets (Table 4).

In conclusion, the results of this study indicate similarities and differences in macromineral absorption between tapirs and horses that are of ecophysiological relevance. For the management of captive tapirs, the results imply that diets designed according to horse requirements should be adequate. Salt licks should be provided, and it should be assured that trace mineral levels, especially those of Cu and Zn, are not lower, and those of Fe not excessively higher than the recommended values for horse maintenance. Given the particularly effective Ca absorption in tapirs, which is interpreted as an adaptation to the high Ca:P ratios in their native forage, the use of lucerne hay as a roughage source in captivity appears adequate.

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Table 1. Tapirs used for digestion trials. Body weights represent estimates. Diets used were either the zoo diets fed to these animals at their facility (characterised by the proportion of roughage and fruits/vegetables in % of the dry matter intake; the difference to 100 represents the proportion of pelleted feeds and/or cereal products) and roughage-only diets (fruits and concentrates only used for management purposes).

Animal	Species	Sex	Age years	Body mass kg	Zoo ration (roughage/produce	Roughage ration in % dry matter)
1	*T. indicus*	m	9	270	33/40	99/1
2	*T. indicus*	f	15	260/255	8/51	98/1
3	*T. terrestris*	f	11	215	23/29	-
4	*T. terrestris*	m	9	195	73/18	-
5	*T. terrestris*	f	1.5	180	48/35	-
6	*T. terrestris*	f	24	185	34/21	-
7	*T. indicus*	m	4	285	18/27	-
8	*T. terrestris*	m	5	215	24/26	--
9	*T. terrestris*	m	1	175	4/33	-
10	*T. terrestris*	f	17	200	11/68	-
11	*T. terrestris*	f	6	225	18/45	-
12	*T. indicus*	f	6	305	10/51	99/-
13	*T. indicus*	m	7	275	12/69	99/1
14	*T. terrestris*	m	22	180	23/44	96/3
15	*T. terrestris*	f	23	185	36/37	98/1
16	*T. terrestris*	m	23	185	12/26	-
17	*T. terrestris*	f	19	185	14/27	-
18	*T. terrestris*	f	2	185	8/32	-

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Table 2. Mineral absorption characteristics in domestic horses (*E. caballus,* literature data; see methods for sources) and tapirs (*Tapirus terrestris* and *indicus*, data generated in the trials summarized in this study).

Mineral	Species	n[1]	dietary mineral concentration	apparent absorption[2]	a[3]	b[3]	R^2
			g/kg DM ± SD (min., max.)	% ± SD (min., max.)			
Ca	*E. cab.*	85	9.2 ± 6.2 (0.7, 26.6)	26[a] ± 68 (-458, 70)	0.41[a]	-0.02	0.68***
	Tapir	24	6.3 ± 3.9 (0.8, 12.6)	68[b] ± 18 (27, 91)	0.80[b]	-0.03	0.97***
P	*E. cab.*	86	3.9 ± 2.2 (0.7, 13.9)	5[c] ± 28 (-123, 59)	0.45[a]	-0.12	0.65***
	Tapir	24	4.2 ± 1.2 (2.1, 5.8)	21[d] ± 17 (-10, 58)	0.17[b]	0.01	0.09
Mg	*E. cab.*	162	1.8 ± 0.7 (0.2, 7.3)	35[a] ± 12 (-16, 67)	0.15[a]	0.03	0.17***
	Tapir	24	3.4 ± 0.7 (2.2, 4.3)	62[b] ± 32 (-27, 94)	0.42[b]	0.06	0.08
Na	*E. cab.*	163	2.4 ± 1.6 (0.1, 16.9)	56 ± 29 (-140, 95)	0.87[a]	-0.06	0.87***
	Tapir	24	1.9 ± 1.4 (0.4, 4.8)	-4 ± 139 (-465, 86)	1.04[b]	-0.10	0.83***
K	*E. cab.*	166	15.2 ± 8.5 (0.5, 36.5)	78[a] ± 9 (45, 94)	0.88[a]	-0.11	0.98***
	Tapir	24	16.1 ± 3.9 (8.1, 22.3)	59[b] ± 13 (31, 88)	0.26[b]	0.50	0.24*
			mg/kg DM ± SD (min., max.)	% ± SD (min., max.)			
Fe	*E. cab.*	18	258 ± 222 (77, 1083)	-42 ± 85 (-268, 54)	0.70[c]	-0.02	0.70***
	Tapir	24	304 ± 165 (88, 504)	-136 ± 167 (-592, 54)	-0.07[d]	-0.03	0.00
Cu	*E. cab.*	21	18.9 ± 11.5 (4.0, 42.3)	23[c] ± 28 (-47, 69)	0.33[a]	-0.03	0.49***
	Tapir	24	16.9 ± 16.8 (4.6, 61.4)	-26[d] ± 72 (-265, 52)	0.61[b]	-0.79	0.88***
Zn	*E. cab.*	21	64 ± 34 (17, 145)	-11 ± 35 (-122, 31)	0.00[c]	-0.74	0.00
	Tapir	24	68 ± 65 (15, 208)	-54 ± 103 (-437, 46)	0.37[d]	-3.11	0.46***

[1]number of observations
[2]defined as (mineral ingested (g) – mineral excreted (g))/mineral ingested(g) * 100)
[3]according to the regression equation: apparently absorbable mineral content = a * mineral content + b; unit: g/100gDM for Ca, P, Mg, Na, K and mg/100gDM for Fe, Cu, Zn.
[a,b,c,d]different superscripts within a column indicate significant differences (a,b: p<0.001; c,d: p<0.01) in the respective parameter for this mineral (apparent absorption: U-test; a: ANCOVA, test for interaction)
***,* regression equations significant at p<0.001 and p<0.05, respectively (Regression analysis, F-test)

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Table 3. Mineral content of the diet of free-ranging lowland tapirs (*T. terrestris*) as compared to temperate browse, grass, tapir zoo diets, and recommendations for maintenance requirements in domestic horses.

Mineral	*T. terrestris* browse[1] mean ± SD	*T. terrestris* fruits[1] mean ± SD	*T. terrestris* stomach contents[2]	Temperate browse[3] mean (range)	Temperate grass[3] mean (range)	Regular tapir zoo diets[2] mean (range)	Maintenance recommendation for horses[4]
g/kg DM							
Ca	5.3 ± 3.2	7.0 ± 9.4	8.3	15.6 (9.3-23.8)	4.8 (2.1-9.7)	5.9 (0.8-12.6)	2.4
P	1.2 ± 0.5	1.1 ± 0.8	3.4	2.7 (1.6-4.7)	2.7 (2.0-3.1)	4.0 (2.1-5.8)	1.7
Ca:P	4.4*	6.4*	2.4	5.8*	1.8*	1.3 (0.4-2.2)	1.4
Mg	2.7 ± 1.4	1.4 ± 1.3	1.5	3.4 (2.0-6.9)	1.5 (0.6-2.7)	3.2 (2.2-4.3)	0.9
Na	2.2 ± 1.3	0.3 ± 0.1	2.1	0.09 (0.01-0.31)	0.05 (0.02-0.08)	2.4 (0.7-4.8)	1.0
K	7.3 ± 12.6	1.4 ± 0.3	10.9	14.9 (7.3-31.8)	21.6 (16.0-27.0)	14.8 (8.1-20.0)	3.0-6.0
mg/kg DM							
Fe	349 ± 290	71 ± 62	315	120 (64-191)	129 (46-391)	282 (88-464)	40-70
Mn	455 ± 472	43 ± 53	-	92 (14-248)	74 (37-147)	-	40
Cu	7 ± 6	11 ± 6	23	11 (7-20)	6 (4-9)	20 (5-61)	10
Zn	32 ± 39	22 ± 7	40	53 (13-121)	19 (15-23)	81 (15-208)	40

[1] (Montenegro 2004; n=37 browse and 4 fruit samples)
[2] this study (n=1)
[3] from DLG (1960)
[4] from NRC (Council 1989), Meyer and Coenen (Meyer and Coenen 2002)
* calculated from means

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Table 4. Mineral content of in the faeces of free-ranging lowland tapirs (*Tapirus terrestris*) and in the faeces of captive tapirs

Mineral	*T. terrestris* faeces[1] mean ± SD	*T. terrestris* faeces[2] mean ± SD (range)	Captive tapir faeces zoo diet[2] mean ± SD (range)	Captive tapir faeces roughage only[2] mean ± SD (range)
g/kg DM				
Ca	2.6 ± 2.1	3.0 ± 3.4 (0.4-9.1)	4.8 ± 2.1 (2.0-10.2)	2.4 ± 0.9 (1.2-3.2)
P	1.4 ± 0.9	2.7 ± 0.8 (1.4-3.6)	10.4 ± 1.9 (6.4-14.0)	6.0 ± 1.2 (4.6-7.4)
Mg	1.2 ± 0.7	2.1 ± 1.0 (0.8-3.1)	3.3 ± 1.8 (1.2-6.9)	2.7 ± 1.6 (0.9-5.0)
Na	2.9 ± 2.5	0.7 ± 0.1 (0.6-0.9)	2.9 ± 2.2 (0.9-9.8)	1.9 ± 0.7 (0.7-2.9)
K	1.8 ± 1.8	8.4 ± 4.6 (2.0-12.8)	18.0 ± 3.6 (12.9-25.3)	17.0 ± 4.4 (13.2-23.5)
mg/kg DM				
Fe	2952 ± 11767	2026 ± 1342 (881-3807)	1981 ± 1431 (703-6108)	915 ± 277 (507-1306)
Cu	43 ± 68	29 ± 4 (23-43)	52 ± 24 (24-100)	19 ± 3 (15-22)
Zn	86 ± 91	39 ± 14 (20-57)	252 ± 147 (91-615)	89 ± 31 (64-150)

[1] (Montenegro 2004; n=37)

[2] this study (n=6 samples from the wild, 18 from animals on regular zoo diets and 6 from animals on roughage only diets)

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Figure 1. Correlations between the mineral content and the absorbable mineral content (g/100g dry matter) in domestic horses (*E. caballus*) and captive tapirs (*Tapirus spp.*) for Ca, P, Mg, Na, K, Fe, Cu, Zn. For significant differences between the species, see Table 2.

Figure 2. Relationship between the dietary Ca:P-ratio and the apparent absorption coefficient for Ca and P in captive tapirs (*Tapirus spp.*)

Figure 3. Relationship between the dietary Ca concentration and the urinary Ca:creatinine-ratio in captive tapirs (*Tapirus spp.*)

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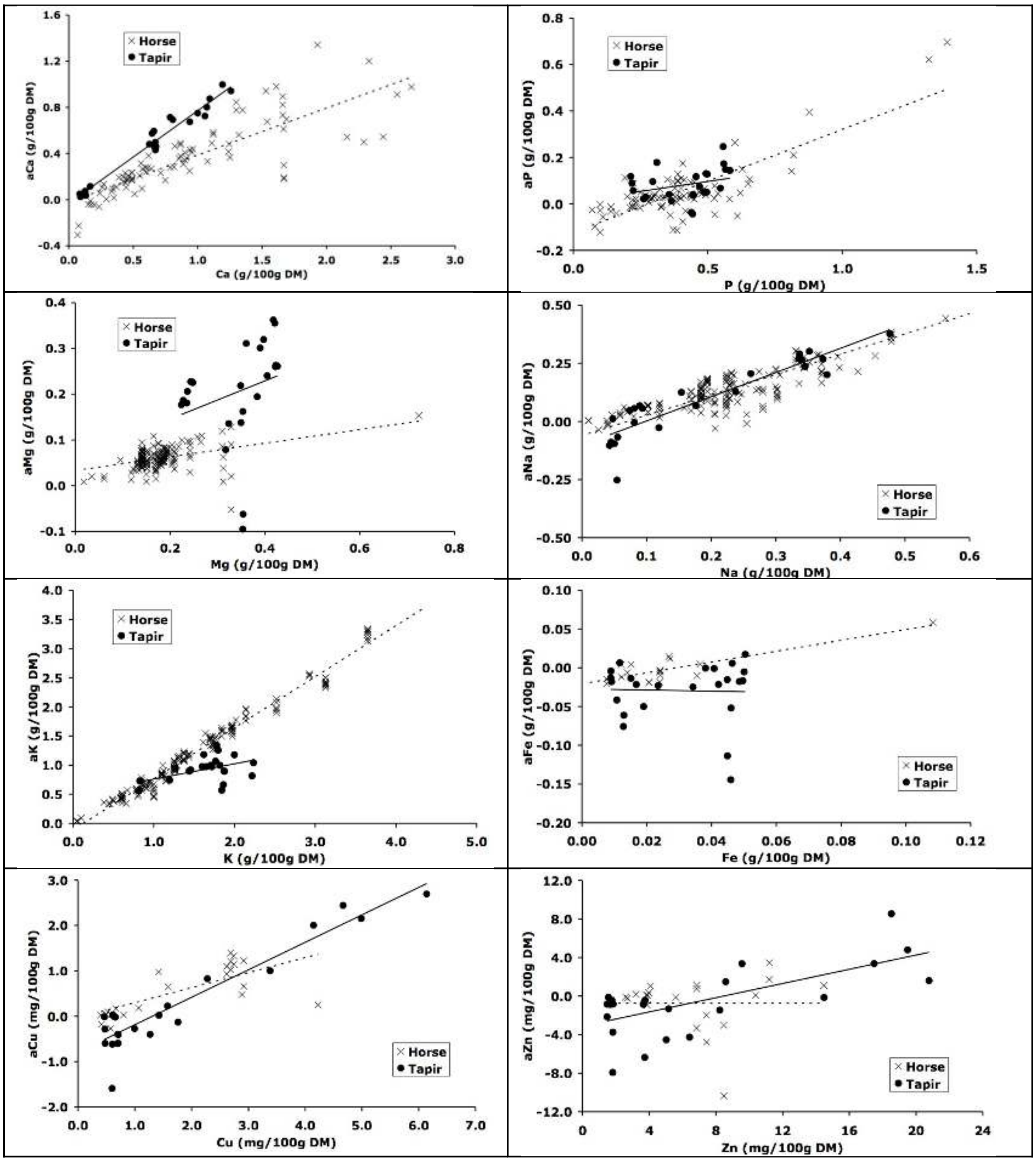

Figure 1. Correlations between the mineral content and the absorbable mineral content (g/100g dry matter) in domestic horses (*E. caballus*) and captive tapirs (*Tapirus spp.*) for Ca, P, Mg, Na, K, Fe, Cu, Zn. For significant differences between the species, see Table 2.

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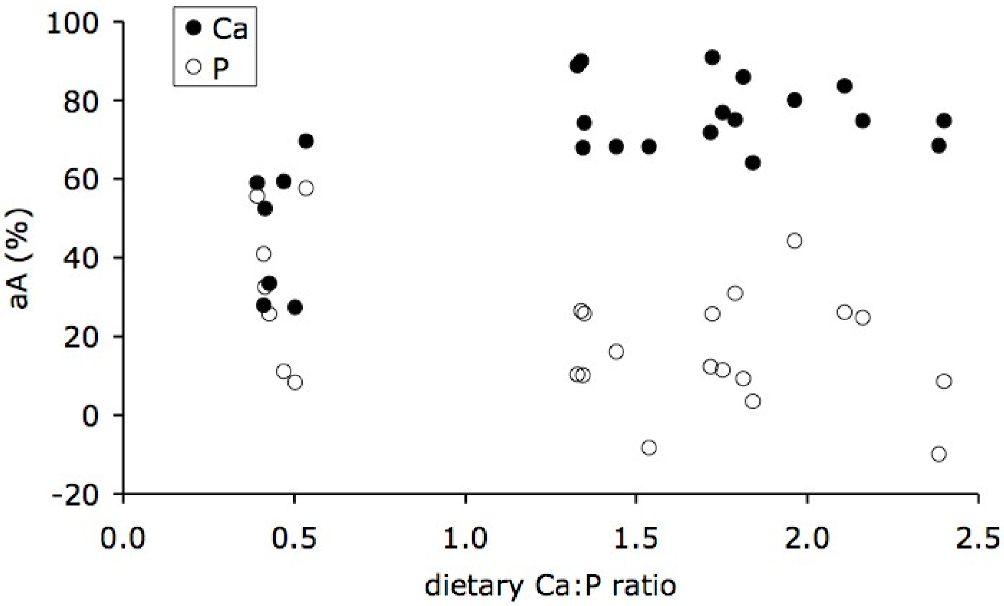

Figure 2. Relationship between the dietary Ca:P-ratio and the apparent absorption (aA) coefficient for Ca and P in captive tapirs (*Tapirus spp.*)

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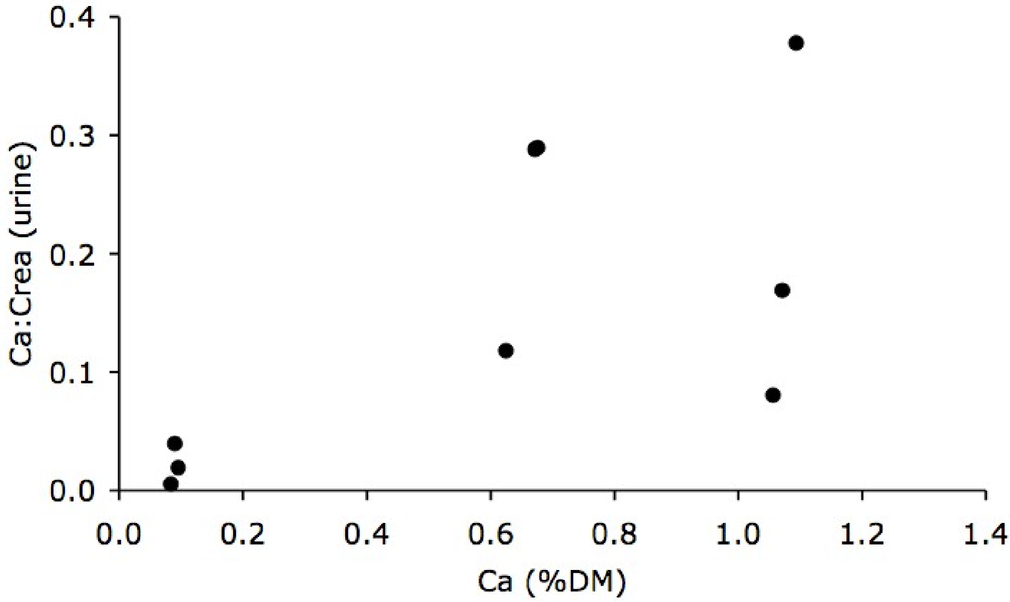

Figure 3. Relationship between the dietary Ca concentration (in % dry matter) and the urinary Ca:creatinine-ratio in captive tapirs (*Tapirus spp.*)