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Effect of moderate work on intake and serum profile of minerals in semi-captive Asian elephants *(Elephas maximus)* fed sugarcane based diet

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Asian elephant (*Elephas maximus*) is an endangered species. In recent times, considerable attention has been paid on *in-situ* and *ex-situ* conservation of the species. Proper nutrition is the key to successful breeding of Asian elephant in captivity. However, only limited information is available on captive feeding of this species, which mostly pertains to feeding value of tree fodders (Nair and Ananthasubramanium 1979), basic data on intake and digestibility of nutrients among different age-group of elephants (Das *et al.* 2015a) and effect of feeding restricted amount of concentrates on nutrient utilization (Das *et al.* 2015b, Clauss *et al.* 2003). In most of the Western zoos they are fed on the basis of the guidelines suggested by the Nutrition Advisory Group (NAG) of Association of Zoo and Aquariums (AZA) which is based on the nutrient requirement for horses. According to this, a diet containing 8–10% CP, 0.3% Ca, 0.24% P, 50 ppm Fe, 10 ppm Cu and 40 ppm Zn would be adequate for maintenance of adult elephant (Ullrey 1997). Although the relative requirements are less, because of size, elephants require large amount of food. Consequently, elephants have adopted a digestive strategy of extracting maximum nutrients from very poor quality roughages with shortest possible time. As a result, they have to continue to eat up to 16–20 h/d (Sivaganeshan 1991) to meet their nutrient requirements. Most of the semi-captive elephants have to work for several hours. Thus, they may not get sufficient time to consume enough forages to fulfill their requisite nutrient requirement especially of minerals. Forages are important sources of minerals in elephant diets. Any reduction in forage consumption may cause deficiency or imbalance of minerals. The information on mineral utilization in Asian elephant mostly pertains to mineral content of forages consumed by elephants (Shrestha *et al.* 1998). Yur *et al.* (2008) indicated that exercise can influence absorption and utilization minerals in horses. The metabolism of minerals in horses and elephants is similar (Clauss *et al.* 2003), hence it would be logical to assume that exercise will influence absorption and utilization of minerals in the Asian elephant also. Thus, it would be desirable to understand the relationship between moderate work and utilization of minerals in semi-captive Asian elephants. Primary objective of this experiment was to study the effect of 4 h of touristic safari on intake, absorption and serum profile of minerals in semi-captive Asian elephants.

The present study was conducted at Jim Corbett National Park, Ramnagar, Uttarakhand, India. Six Adult female elephants (6), 20–60 year-old, weighing 2,514–3,684 kg were divided into 2 groups of 3 each. Animals in group1 did not perform any work while those in group 2 performed 4 h of touristic work. Two feeding trials of 15 d duration were conducted on each of the elephants. All animals were provided night shelter from 17: 30 PM to 5: 30 h with facility for individual feeding and collection of faeces. During this period, measured amount of wheat *rotis*, sugarcane *(Saccharum officinarum)* and cut branches of *Ficus religiosa* were offered to them. Rest of the time they were allowed to forage in the nearby grassland/forest. Digestion trial was conducted during days 11–15 of each period to measure the intake and apparent absorption of nutrients. Representative samples of forages consumed during foraging were also sampled. Feed consumption during foraging was measured indirectly using lignin as an internal marker. Blood samples were collected from individual elephants on day 15 and 30 of the trial. Proper management and sanitary guidelines as suggested by the Central Zoo Authority were followed during the course of experimentation (CZA 2000). Body measurements were taken on day 1, 10, 15, 26 and 30 of the trial to calculate body weight according to Hile *et al.* (1997).

Dry matter of ground samples of feed/forages offered, refusals and faeces (AOAC 2005), calcium (Talapatra *et al.* 1940), phosphorus (AOAC 2005) were estimated. Serum concentration of Ca and P was estimated using diagnostic kits. Concentration of Co, Cu, Fe and Zn in the feed, faeces and serum samples was analyzed by wet digestion using atomic absorption spectrophotometer. Data generated were analyzed using student's "t" test and treatment means were tested by applying Tukey's test by using SPSS software package, version 13.

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Tree branches (bark and stem) used in the present experiment contained less Ca than that reported by Singh *et al.* (2009). Such differences could be due to part of the plant used for analysis (Table 1). We used whole branches comprising leaves, barks and stems whereas Singh *et al.* (2009) analyzed only leaves, which contain more Ca. Shrestha *et al.* (1998) reported that stems and twigs of *Ficus religiosa* contained 13, 152 and 22 ppm of Cu, Fe and Zn, respectively, which is similar to the present findings. Tree branches consumed by elephants in both the groups were similar as tree branches were offered at the same rate. Intake (kg/1,000 kg BW/d) of sugarcane and sugarcane leaves was higher (P<0.01) in group 1 as sugarcane was available with them for most of the time (Table 2). Elephants in group 2 continued foraging during work also. As a result, elephants in group 2 consumed more (P<0.01) forages than those in group 1. This way the working elephants compensated the lower intake of sugarcane by increasing forage consumption. Consequently, average daily dry matter intake (DMI) was comparable in both the groups suggesting that intake is not influenced by 4 h of touristic work.

Table 1. Dry matter and mineral content of feeds and forages fed to non-working and working semi-captive Asian elephants

Parameters	Sugarcane	Sugarcane leaves	Roti	Tree branches[§]	Forages[#]
Dry matter (%)	41.3	34.0	52.8	48.1	40.15
Mineral content (% DM)					
Ca	0.40	0.40	0.27	1.28	0.81
P	0.18	0.18	0.63	0.45	0.22
Mineral content (mg/ kg DM)					
Co	3.25	3.16	3.15	4.81	4.8
Cu	5.62	3.92	12.2	10.8	9.72
Fe	172	107	53.1	156	110
Zn	16.3	13.9	42.5	52.2	17.2

[§]Tree branches of *Ficus religiosa*; [#]21 species of forages were consumed during foraging; ppm, parts per million

Table 2. Feed Consumption and mineral contents of diets fed to non-working and working semi-captive Asian elephants

Parameters	Groups		SEM
	Group 1	Group 2	
Feed consumption (kg/1000 kg BW/day)			
Roti	1.11±0.03	1.11±0.02	0.016
Sugarcane**	8.63±0.22	7.54±0.19	0.216
Sugarcane leaves**	2.50±0.07	2.20±0.05	0.062
Tree branches	2.38±0.10	2.26±0.03	0.052
Forages**	3.93±0.09	4.71±0.10	0.133
DMI	18.6±0.38	17.8±0.35	0.272
Mineral content of diet (%)			
Ca**	0.59±0.002	0.61±0.002	0.003
P	0.25±0.002	0.25±0.001	0.001
Mineral content of diet (ppm)			
Co**	3.76±0.01	3.84±0.01	0.013
Cu**	7.32±0.02	7.56±0.02	0.039
Fe**	141±0.2	138±0.1	0.438
Zn	22.4±0.18	22.4±0.07	0.092
Body weight (kg)	3408±62.5	3474±49.8	39.355

Means (±standard error) with different * differ significantly *(P<0.05) and **(P<0.01); SEM, Standard error of mean; ppm, parts per million; DMI, dry matter intake; Elephant in group 1 perform no work and those in group 2 perform 4 hour's tourist safari (work)

Table 3. Intake, outgo and apparent absorption of minerals in non-working and working semi-captive Asian elephants

Parameters	Groups		SEM
	Group 1	Group 2	
Calcium (Ca)			
Intake (mg/kg BW)	110±2.1	109±1.9	1.378
Outgo (mg/kg BW)*	74.5±1.33	69.051.38	1.232
Apparent absorption (%)**	32.2±0.34	36.7±0.39	0.724
Phosphorus (P)			
Intake (mg/kg BW)	46.5±0.96	45.1±0.80	0.629
Outgo (mg/kg BW)*	36.0±1.33	32.3±0.64	0.901
Apparent absorption (%)*	22.5±2.26	28.4±0.43	1.418
Cobalt (Co)			
Intake (µg/kg BW)	69.8±1.35	68.5±1.31	0.921
Outgo (µg/kg BW)*	57.2±1.21	51.7±1.29	1.178
Apparent absorption (%)**	18.2±0.40	24.5±0.69	1.036
Copper (Cu)			
Intake (µg/kg BW)	136±2.5	135±2.5	1.686
Outgo (µg/kg BW)	117±2.6	111±2.5	1.977
Apparent absorption (%)**	14.1±0.79	17.9±0.54	0.740
Iron (Fe)			
Intake (µg/kg BW)	2615±57	2462±50	43.24
Outgo (µg/kg BW)*	2436±52	2247±49	44.45
Apparent absorption (%)**	6.85±0.20	8.74±0.28	0.33
Zinc (Zn)			
Intake (µg/kg BW)	415±9	400±7	5.938
Outgo (µg/kg BW)	371±8	355±6	5.363
Apparent absorption (%)	10.6±0.72	11.3±0.76	0.514

Means (±standard error) with different * differ significantly *(P<0.05) and **(P<0.01); SEM, Standard error of mean; Elephant in group 1 perform no work and those in group 2 perform 4 hour's tourist safari (work).

Intakes of all minerals were comparable in both groups. However, the absorption of all minerals except Zn was higher in group 2 than group 1 (Table 3). Apparent absorption of Ca was higher (P<0.01) in group 2. Increased calcium absorption in group 2 was expected as increase in the concentration of 1, 25-$(OH)_2D_3$, a potent hormone responsible for intestinal absorption of Ca. Similarly, endurance exercise was reported to stimulate intestinal Ca absorption in human and rats (Zittermann *et al.* 2002). However, increased absorption of Ca in group 2 was not reflected in their serum Ca concentration (Table 4). Similar to the present study, the serum concentrations of calcium remained unchanged in exercising and non-exercising horses (Yur *et al.* 2008) as serum calcium concentration is a hormonally controlled process. Elephants in group 2 absorbed more (P<0.05) P than those in group 1. Exercise resulted in increased phosphorus balance in rat (Yeh *et al.*

Table 4. Serum mineral profile of non-working and working semi-captive Asian elephants

Serum minerals	Groups		SEM
	Group 1	Group 2	
Ca (mg/dl)	7.27±0.94	7.91±2.10	1.040
P (mg/dl)	3.63±0.47	3.95±1.05	0.520
Co (ppm)	1.49±0.16	2.31±0.32	0.243
Cu (ppm)	1.52±0.08	2.01±0.19	0.144
Fe (ppm)*	2.17±0.16	3.17±0.18	0.248
Zn (ppm)**	1.70±0.08	2.88±0.14	0.273

Means (±standard error) with different * differ significantly *($P<0.05$) and **($P<0.01$); SEM, Standard error of mean; Elephant in group 1 perform no work and those in group 2 perform 4 h tourist safari (work).

1989). However, increased absorption of P in group 2 was not reflected in their serum P concentration. All the diets supplied adequate amount of Ca and P to fulfill their requirement (Ullrey 1997). In most of the captive facilities in India, elephant diet is supplemented with tree fodder and cereals which are rich source of Ca and P, respectively. Thus, in practical feeding situation Ca and P deficiency is unlikely to occur.

Absorption of Co was higher ($P<0.01$) in group 2 than in group 1. Similar increase in absorption of Co has been reported in humans due to work (Gleizes *et al.* 1999). Increased Co absorption could be a contributing factor for improved microbial profile of working elephants (Katole *et al.* 2014) as cobalt is an essential nutrient for growth of hindgut microbiota. Increased absorption of Co in group 2 was, however, not reflected in their serum Co concentration. Cobalt content of both the diets in the present study was sufficient to meet the maintenance requirements (Ullrey 1997). The apparent digestibility of Cu in the present experiment was higher ($P<0.01$) in group 2. This could be correlated with increased erythropoiesis in working elephants (Bothwell *et al*. 1958). Copper content of diet was 7.3 and 7.6 ppm in elephants of groups 1 and 2, respectively, both are deficient as per the recommendation (Ullrey 1997). Thus, a suitable supplementation with adequate amount of copper would be desirable.

The apparent digestibility of Fe was higher ($P<0.01$) in group 2 than group 1. Similarly, physical exercise increased absorption of iron in horses (Yur *et al.* 2008).This may be due to increased erythropoietin in working elephants. In working animal, rate of erythropoiesis was positively correlated with absorption of iron (Bothwell *et al.* 1958). This increased absorption of Fe in elephants of group 2 was also reflected in serum Fe concentration. Similarly, serum Fe level increased in Wister rats after exercise (Rowsey *et al.* 2009). The intake, outgo and absorption of Zn were comparable in both groups. However, serum concentrations of Zn in elephants of group 2 were higher ($P<0.01$) than those in group 1. Similarly, increased serum Zn concentration was observed in human subjects following exercise (Buchman *et al.* 1998).

SUMMARY

Two feeding trials were conducted to study the effect of moderate work on intake and serum profile of minerals in semi-captive Asian elephants (*Elephas maximus*). Six elephants were divided into 2 groups. Animals in group 1 performed no exercise while those in group 2 performed 4 h of moderate work. During both the trials, all elephants were fed a basal diet comprising wheat-*roti*, sugarcane and tree leaves. Intake of sugarcane was higher in group 1 while forage intake was higher in group 2. Serum concentration of Fe and Zn was higher in group 2. Apparent absorption of Ca, P, Fe and Cu was higher in group 2. It is evident that 4 h of moderate exercise has no adverse impact on intake and serum profile of minerals; rather it improved the serum concentrations of Fe and Zn. It was concluded that 4 h of touristic work is beneficial for semi-captive Asian elephants.

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