

A Survey Of African (*Loxodonta africana*) And Asian (*Elephas maximus*) Elephant Diets And Measured Body Dimensions Compared To Their Estimated Nutrient Requirements

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Nineteen zoos completed a survey between 1997 and 1998 detailing information on their elephants including: species (African; *Loxodonta africana* or Asian; *Elephas maximus*), sex, weight, height, girth, length, and age. Captive female African (3375 kg) and Asian (3453 kg) elephants appeared heavier than published data for their free-ranging counterparts (2800 and 2720 kg, respectively). Elephant weight and dimension information from the survey served as a tool to evaluate the condition of the captive elephants. Fifteen of the 19 surveyed zoos that housed 22 African and 29 Asian elephants completed a three-day diet intake study. Calculated nutrient intake was compared to estimated elephant nutrient requirements. At least one nutrient was low in all diets reviewed. Every institution had elephant diets deficient in at least two nutrients and several zoos had elephant diets that were deficient in almost every nutrient when compared to suggested elephant requirements. Those nutrients found low for elephant diets in one or more institutions included: selenium, riboflavin, vitamin D, thiamin, iodine, zinc, vitamin E, copper, iron, crude protein, cobalt, manganese, vitamin A, sodium, and phosphorus. However, elephants at all the zoos were reportedly healthy. Since possible nutrient inadequacies may potentially go unnoticed for long periods of time, results from this study illustrate the importance of evaluating the diets of captive elephants.

Key words: intake study; protein; minerals; vitamins

INTRODUCTION

Available data on nutrient levels consumed by large numbers of captive African and Asian elephants are limited. However, the nutrient content of typical free-ranging elephant diets have been published [Bax and Sheldrick, 1963;

Shrestha et al., 1998]. Since elephant nutrient requirement data are limited, information for horses (another large hindgut fermenter) is often applied to elephants [Roehrs et al., 1989; Stevens and Hume, 1995]. Information on free-ranging elephant diets used in conjunction with the National Research Council's nutrient requirements for horses has provided a basis for establishing estimated daily nutrient target levels for elephants [NRC, 1989; Ullrey et al., 1997]. By calculating the nutrient composition of items consumed by elephants, the level of nutrients consumed can be compared to the estimated nutrient requirements to determine the adequacy of the diets.

Various captive animal species have been classified as overweight when compared to their free-ranging counterparts [Morris, 1998; Wright, 1995]. Body condition data from the current study provided a relatively large number of animals by which free-ranging and captive elephants could be compared to determine if captive elephants are also overweight compared to their free-ranging counterparts.

MATERIALS AND METHODS

A total of 19 zoos (three European and 16 from the USA) completed a survey reporting detailed information on each elephant in their collection including: species (African or Asian), sex, weight, height, girth, length and age (infant (0-5 yr), growing (6-12 yr), adult (13-44 yr), geriatric (>45 yr) [Nowak, 1999]. All elephants were reportedly healthy at the time of the survey. Zoos surveyed included: Dierenpark Amersfoort (Netherlands), Baltimore Zoo, Birmingham Zoo, Wildlife Conservation Society, Brookfield Zoo, Buffalo Zoological Gardens, Buttonwood Zoo, Chehaw Zoo, Cheyenne Mountain Zoo, Indianapolis Zoo, Lincoln Park Zoological Gardens, Miami Metrozoo, Riddle Elephant Sanctuary, Roger Williams Park Zoo, Rosamond Gifford Zoo at Burnet Park, Rotterdam Zoo-Diergaarde Blijdorp (Netherlands), San Francisco Zoological Gardens, Seneca Wild Animal Park and Whipsnade Wild Animal Park (England). When the female elephant body measurements were calculated separately by species, the one female infant in the study was excluded. This animal was less than 5 years of age and would have skewed the results.

At 15 of the 19 zoos, dietary intake studies were performed. The weight of each diet item offered to and consumed by the elephants was tabulated for three consecutive days for each individual animal, (or group of animals if they were not separated for feeding). Dietary biotin, calcium (Ca), cobalt (Co), copper (Cu), crude protein, iodine (I), iron (Fe), phosphorus (P), manganese (Mn), magnesium (Mg), potassium (K), riboflavin, selenium (S), sodium (Na), sulfur (S), thiamin, vitamin A, vitamin D, vitamin E, and zinc (Zn) content were calculated using the Animal Nutritionist program. Information on the nutrient content of the pelleted feeds, hays, and any other items fed (such as produce, browse, and bread) was obtained from the institutions. When available, the nutrient content of the hays was based on chemically analyzed values. Dietary nutrient content was compared to estimated elephant nutrient requirements [Ullrey et al., 1997].

Means and standard errors (SEM) were calculated using SPSS for Windows (Rel. 9.0.0 SPSS Inc., Chicago, Illinois).

RESULTS AND DISCUSSION

Size Dimensions

Elephant size variation primarily was due to the sex and age of the animals (Table 1). Published free-ranging African elephant weights are 2,800 kg (females) and 6,000 kg (males) [Nowak, 1999; Macdonald, 1999]. Published free-ranging female and male Asian elephant weights are 2,720kg and 5,400kg, respectively [Nowak, 1999; Macdonald, 1999]. The weight and dimension information reflects data from 9 males and 53 females. Thus most of the conclusions are based on female animals.

Captive female elephants weighed more than their free-ranging counterparts by 600 to 700 kg (Table 1). Girth size of Asian elephants was larger than African elephants. The female Asian elephants were heavier, and slightly shorter in height and length than the female African elephants. Although weight management is a concern for both captive African and Asian elephants, the body size of captive female Asian elephants may be more of a concern given their comparison to the weight of free-ranging elephants and the body dimensions of captive African elephants. Reportedly, none of the female elephants in this study were gestating at the time of body measurements so that was not the cause for the girth size or body weight.

Diet Analysis

Underlying nutritional deficiencies may exist for long periods of time without a noticeable clinical effect. Thus diets should be periodically analyzed for nutrient content. The elephant diets in every institution was deficient in at least two recommended nutrients and several zoos were deficient in almost every nutrient when compared to the requirements suggested by Ullrey et al. [1997] (Tables 1-3). Not every hay sample provided by each zoo was analyzed for every nutrient thought to be required by elephants. Missing nutrient values in hay were not included as contributing to the nutrient profile of the total diet. Thus it is possible that some nutrients were underestimated in this survey. Hay analysis results differed widely among zoos. Hay quality differs with season, how the hay is handled during harvesting, time of cutting, type of soil, etc. Thus, it cannot be assumed that hay alone meets estimated elephant nutrient requirements. As a result, hays should be analyzed periodically to ascertain its actual nutrient content. The majority of zoos fed a pelleted diet formulated for ungulates that contained a wide array of nutrients. The combination of hay and pellets would have met the estimated elephant nutrient requirements if the hay had been a higher quality and/or had the institutions used more pelleted feed in the diet. It is a practice in some domestic livestock industries to consider the hay/base diet to contain only limited nutrients when calculating the nutrient content for appropriate diets. The National Research Council states that it is important to know the nutrient composition and bioavailability of all feed ingredients used, however many farmers do not have the resources to accurately determine these measurements with the frequent feed ingredient proportion changes caused by least cost diet formulation (NRC, 1998; NRC, 2001).

Therefore, some domestic livestock diet formulations consider the vitamin and mineral content of the hay/base diet as almost nil and the pelleted diet is formulated to supply the majority of vitamins and minerals required. Due to the rapid digestion and low absorption rate of hay by elephants perhaps, it is appropriate to adopt this concept for elephants to ensure that their diets meet estimated vitamin and mineral requirements (Van Soest, 1982). This concept may need to be used by zoos until every zoo is able to consistently and completely measure all nutrients in every elephant's diet and until true feed digestibilities for elephants are determined.

Protein: Five of 15 zoos had deficient levels of dietary crude protein (Table 2.) [Ullrey, 1997]. Deficient crude protein levels may be problematic especially with young animals. As an example, young elephants mistakenly fed protein levels at approximately 5.5% resulted in Kwashiorkor and Marasmus disease and the ultimate death of 8 out of 63 animals before the problem was corrected [Ullrey et al., 1985].

Minerals: As seen in Table 2, Ca, K, and Mg were adequate in all diets. Some diets were calculated as deficient in one or more of the following minerals: Co, Cu, Fe, I, Mn, Na, P, Se and Zn (Tables 2-3). Although some zoos did offer trace mineral salt blocks, these did not always contain all of the required minerals and, therefore, did not supplement the diet adequately. In contrast, many of the salt blocks add minerals in extremely high (possibly toxic) levels if consumed in large quantities and when added to the mineral content already available in the pelleted feeds.

Vitamins: Vitamins were not analyzed for the hays so vitamin levels may have been underestimated in the consumed diet. However, since these levels can change dramatically from supplier to supplier and harvest to harvest, hay can not be considered a constant contributor of vitamins in the elephant diet. Vitamin A is considered an essential nutrient [NRC, 1989] and it was low when compared to the estimated requirement for three zoos [Ullrey et al., 1997]. Carotenoids may be converted to vitamin A so the actual level of deficiency is unknown. Vitamin D was low for 12 zoos [Ullrey et al., 1997]. However, vitamin D may be synthesized in the elephant skin similar to horses upon exposure to ultraviolet light [NRC, 1989]. Since many elephants in captivity are housed without natural sunlight during the winter, care must be taken to ensure appropriate dietary vitamin D levels at least during these times. Vitamin E was below estimated requirements at 6 institutions [Ullrey et al., 1997]. Captive elephants have been reported to have lower circulating tocopherol levels than free-ranging animals and elephants can well utilize water-soluble forms of vitamin E [Dierenfeld and Dolensek, 1988; Wallace et al., 1992]. A number of studies have reported an increased plasma concentration of tocopherol when supplemental vitamin E in water soluble or miscible forms are used [Ullrey et al., 1997]. While vitamin E is relatively non-toxic, over supplementation as shown by one zoo in this study feeding 1535 mg/kg, DMB (dry matter basis; 15 times the recommendation) may be of concern. Eleven zoos had deficient dietary thiamin (B₁) and 13 had riboflavin (B₂) deficient levels [Ullrey et al., 1997]. Thiamin (B₁) and riboflavin

(B₂) in horses are synthesized in the gastrointestinal tract [NRC, 1989]. Elephants, being hindgut fermenters, may similarly synthesize these vitamins. Thus low levels may not be of primary concern.

CONCLUSIONS

A pelleted diet formulated to compliment each zoo's hay should be fed to elephants to provide nutrients at adequate levels. It is important to analyze both hay and pellets to ensure an appropriate compliment of nutrients that together meet estimated elephant nutrient requirements as reported by Ullrey, et al. [1997]. These analyses should periodically include crude protein as well as, vitamins and minerals. Results from this study illustrate the importance of evaluating the diets of captive elephants. In addition, captive elephant diets need to be further examined to determine the link between body size, health and dietary requirements.

REFERENCES

- Bax PM, Sheldrick DLW. 1963. Some preliminary observations of the food of elephant in the Tsavo Royal National Park (East) of Kenya. *E Afr Wildl J* 1:40-53.
- Dierenfeld E, Dolensek EP. 1988. Circulating levels of vitamin E in captive Asian elephants (*Elephas maximus*). *Zoo Biol* 7:165-72.
- Macdonald D. 1999. *The Encyclopedia of Mammals*. Barnes and Nobles Inc. and Facts on File.
- Morris PA. 1998. Hedgehog rehabilitation in perspective. *Vet Rec* 143:633-6.
- National Research Council. 1989. *Nutrient Requirements of Horses*. Washington, DC: National Academy of Sciences.
- National Research Council. 1998. *Nutrient Requirements of Swine: Tenth Revised Edition*. Washington, DC: National Academy of Sciences.
- National Research Council. 2001. *Nutrient Requirements of Dairy Cattle: Seventh Revised Edition*. Washington, DC: National Academy of Sciences.
- Nowak RM. 1999. *Walker's Mammals of the World Vol. I (6th Ed.)*. Baltimore, MD: The John Hopkins University Press.
- Roehrs JM, Brockway CR, Ross DV, Reichard TA, Ullrey DE. 1989. Digestibility of Timothy Hay by African Elephants. *Zoo Biol* 8:331-7.
- Shrestha SP, Ullrey DE, Bernard JB, Wemmer C, Kraemer DC. 1998. Vitamin E and other analyses in plasma of Nepalese camp elephants (*Elephas maximus*). *J Zoo Wildl Med* 23:269-78.

Stevens CE, Hume ID. 1995. In: Comparative Physiology of the Vertebrate Digestive System. 2nd ed. New York, NY: University of Cambridge.

Ullrey DE, Jacobson ER, Kollias GV, Ku PK, Whetter PA. 1985. Kwasiorkor and Marasmus in baby elephants. Scottsdale, AZ: Proc Am Assoc of Zoo Vets.

Ullrey DE, Crissey S, Hintz H. 1997. Elephants: Nutrition and Dietary Husbandry. In: Allen ME, Edwards MS, Roocroft A., editors. Nutrition Advisory Group Handbook Factsheet 004.

Van Soest, PJ. 1982. Nutritional Ecology of the Ruminant: ruminant metabolism, nutritional strategies, the cellulolytic fermentation and the chemistry of forages and plant fibers. Ithaca, NY: Cornell University Press.

Wallace C, Ingram KA, Dierenfeld ES, Stuart RL. 1992. Serum vitamin E status in captive elephants during prolonged supplementation of micelled natural alpha-tocopherol. Oakland, CA: Proc Intl Conf Am Assoc Zoo Vets and Am Assoc Wildl Vets. Pp. 388-94.

Wright BW. 1995. A novel enrichment program reduces lethargy in orangutans. *Folia Primatologica* 65:214-18.

TABLE 1. Elephant size dimension comparisons by age category, sex, and species

Dimension	Infant (0-5yr)	Growing (6-12yr)	Adult (13-44yr)	Geriatric (≥45)	Female	Male	All African	All Asian	Female African	Female Asian ¹
Girth, cm	175,	216,	264,	297,	372,	345,	361,	373,	360,	381,
	n=3	n=10	n=56	n=3	n=41	n=9	n=23	n=27	n=18	n=23
Height, cm	170,	226,	252,	267,	245,	250,	249,	241,	244,	243,
	n=2	n=7	n=41	n=2	n=43	n=9	n=23	n=29	n=18	n=25
Length, cm	216,	254,	312,	307,	304,	299,	318,	290,	321,	292,
	n=2	n=4	n=43	n=2	n=42	n=9	n=22	n=29	n=17	n=25
Weight, kg	1222,	2473,	3549,	4115,	3385,	3470,	3365,	3430,	3375,	3453,
	n=2	n=6	n=51	n=3	n=53	n=9	n=31	n=31	n=26	n=26

¹There was only 1 infant female elephant. This Asian elephant was less than 5 years old and she was not included when calculating the separated female averages due to the fact that she would skew the results

TABLE 2. Calculated mean intake of crude protein and macro minerals for both Asian and African elephants at 15 zoos included in survey (as fed basis)

basic)

Zoo	Asian	African	CP	Ca	P	Mg	K	Na
	N		%					
1	0	2	9.9	0.56	0.29	0.20	1.8	0.15
2	2	0	13.8	0.63	0.35	0.20	1.3	0.14
3	4	0	<u>6.6</u> ²	0.34	0.21	0.11	1.2	0.03
4	0	3	<u>6.1</u>	0.32	<u>0.11</u>	0.13	0.8	<u>0.05</u>
5	3	0	<u>7.8</u>	0.40	0.22	0.15	1.2	0.15
6	2	0	<u>7.8</u>	0.33	0.24	0.19	1.3	0.18
7	0	2	12.0	0.65	0.45	0.21	1.8	0.18
8	0	2	11.0	0.64	0.28	0.15	2.0	0.12
9	0	5	13.7	0.70	0.21	0.19	1.9	0.12
10	1	1	10.4	0.45	0.33	0.23	1.6	0.12
11	0	3	11.0	0.61	0.31	0.18	1.2	0.37
12	7	0	11.1	0.63	0.30	0.27	1.9	<u>0.05</u>
13	8	0	11.0	0.35	0.26	0.11	1.2	0.28
14	2	2	11.5	0.51	0.38	0.21	1.9	0.17
15	0	2	<u>7.8</u>	0.46	0.28	0.12	1.7	<u>0.09</u>
Mean			10.1	0.50	0.28	0.17	1.5	0.15
SEM			0.62	0.03	0.02	0.01	0.09	0.02
Requirements ¹			8-12	0.3-7	.2-.4	0.10	.4-.5	0.1

¹Estimated nutrient requirements are based on Ullrey et al. [1997].

²Values that are underlined do not meet the estimated nutrient requirements.

TABLE 3. Calculated mean intake of trace minerals for both Asian and African elephants at 15 zoos included in survey

Zoo	Asian	African	Co	I	Se	Fe	Zn	Cu	Mn
	<i>N</i>		ppm						
1	0	2	0.16	<u>0.22</u>	<u>0.14</u>	<u>45</u>	47	9.7	87
2	2	0	0.24	<u>0.45</u>	<u>0.21</u>	138	65	16.5	80
3	4	0	<u>0.03</u>	<u>0.10</u>	<u>0.04</u>	<u>16</u>	<u>9</u>	<u>1.1</u>	<u>9</u>
4	0	3	<u>0.02</u>	<u>0.01</u>	<u>0.02</u>	57	<u>22</u>	<u>7.0</u>	56
5	3	0	<u>0.05</u>	<u>0.06</u>	<u>0.07</u>	100	<u>17</u>	13.8	48
6	2	0	0.18	<u>0.29</u>	0.10	93	<u>36</u>	10.9	47
7	0	2	0.63	1.03	<u>0.14</u>	543	77	13.9	209
8	0	2	0.11	<u>0.33</u>	<u>0.06</u>	<u>27</u>	<u>17</u>	<u>2.8</u>	<u>13</u>
9	0	5	0.15	<u>0.51</u>	<u>0.11</u>	<u>41</u>	<u>28</u>	<u>4.4</u>	<u>22</u>
10	1	1	0.14	<u>0.32</u>	<u>0.16</u>	78	49	10.0	48
11	0	3	0.54	0.65	<u>0.07</u>	435	287	15.0	54
12	7	0	<u>0.08</u>	<u>0.12</u>	<u>0.05</u>	<u>45</u>	<u>21</u>	<u>4.0</u>	<u>20</u>
13	8	0	n/a	n/a	<u>0.02</u>	<u>7</u>	<u>7</u>	<u>1.1</u>	<u>7</u>
14	2	2	0.17	<u>0.52</u>	<u>0.12</u>	120	50	10.6	81
15	0	2	<u>0.09</u>	1.19	0.04	125	32	15.6	74
Mean			0.18	0.41	0.09	125	51	9.1	57
SEM			0.05	0.09	0.01	39.9	17.7	1.39	12.9
Requirements ¹			.10	0.60	0.20	50.0	40.0	10.0	40.0

¹Estimated nutrient requirements are based on Ullrey et al. [1997].

²Values that are underlined do not meet the estimated nutrient requirements.

TABLE 4. Calculated mean intake of vitamins for both Asian and African elephants at 15 zoos included in survey

Zoo	Asian	African	Vit A	Vit D	Vit E	B ₁	B ₂
	<i>N</i>			IU/kg		ppm	
1	0	2	14.0	<u>0.61</u> ²	144	<u>1.4</u>	<u>1.7</u>
2	2	0	3.6	<u>0.51</u>	140	<u>2.6</u>	4.0
3	4	0	7.1	n/a	108	<u>1.0</u>	<u>1.4</u>
4	0	3	11.0	<u>0.04</u>	195	<u>0.6</u>	<u>0.7</u>
5	3	0	<u>2.6</u>	<u>0.36</u>	<u>92</u>	<u>1.0</u>	<u>2.0</u>
6	2	0	<u>2.2</u>	<u>0.15</u>	<u>14</u>	<u>0.8</u>	<u>1.3</u>
7	0	2	28.3	2.27	147	7.4	3.3
8	0	2	<u>2.6</u>	<u>0.27</u>	<u>69</u>	4.2	<u>1.4</u>
9	0	5	3.0	<u>0.47</u>	120	6.9	<u>2.1</u>
10	1	1	4.1	<u>0.33</u>	160	<u>2.3</u>	<u>2.6</u>
11	0	3	17.0	0.88	<u>57</u>	<u>0.9</u>	<u>1.3</u>
12	7	0	6.6	<u>0.07</u>	1535	<u>0.2</u>	<u>0.2</u>
13	8	0	14.6	<u>0.21</u>	<u>10</u>	<u>0.3</u>	<u>0.3</u>
14	2	2	6.4	<u>0.49</u>	125	7.2	<u>2.5</u>
15	0	2	3.8	<u>0.24</u>	<u>54</u>	<u>0.7</u>	<u>1.6</u>
Mean			8.5	0.46	198	2.5	1.8
SEM			1.89	0.14	96.5	0.68	0.27
Requirements ¹			3.0	.80	100	3.0	3.0

¹Estimated nutrient requirements are based on Ullrey et al. [1997].

²Values that are underlined do not meet the estimated nutrient requirement.