

# EVALUATION OF DIETS OFFERED TO ELEPHANTS IN BRAZILIAN ZOOS

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## Abstract

In order to improve the quality of life for captive elephants maintained in Brazilian zoos, the Brazilian Society of Zoos and Aquariums (SZB) organized a workshop concerning management of elephants in zoos in November 2014. Evaluation of nutritional husbandry was identified as a priority. Thus, diets were assessed from information obtained for 4 African (*Loxodonta africana*) and 12 Asian (*Elephas maximus*) elephants held in 7 of 11 Brazilian zoos that maintain elephants. Animal body weights, diet ingredients and quantities offered were collected by survey; nutrient profiles of diets were assessed using local food composition tables and calculated using the software Zootrition®. Excess dietary energy (up to 280% of estimated needs) appeared most problematic, due to high amounts of foods offered, as well as elevated proportions of highly digestible components in the diets offered (up to 20% of calories from fruits and vegetables, and 33% from concentrate pellets in the dry matter (DM)). This may lead to overcondition (obesity) and concurrent health problems. A high level of sugar content ( $4.9 \pm 2.5\%$  of DM) was found in diets from four zoos that use sugarcane as forage; replacement with sugarcane bagasse (by-product of juice extraction) may be a way to decrease the sugar content and digestibility of those diets. A majority of the zoos surveyed (6/7) also fed diets that may have been higher in crude protein ( $10.9 \pm 2.4\%$  of DM) than necessary for maintenance requirements of adult elephants (~6 to 8% of DM, with values ranging from 7.6 to 15.4% of DM). As a result of the initial diet assessment, one zoo reformulated its diet to better meet calculated energy and protein needs; a >50% reduction in dietary energy content, and slight increase in protein content, resulted in substantially improved body condition after 3 mo. Beyond identifying problems in the amount of energy supplied to elephants in Brazil, this study also shows that significant change is possible, provided that appropriate nutritional management is applied within the zoos.

## Introduction

Classified by the IUCN red list (2014) as endangered and vulnerable, respectively, Asian (*Elephas maximus*) and African (*Loxodonta africana*) elephants are popular zoo exhibit species, and as such can provide excellent conservation and environmental education messaging. As with other species, appropriate nutrition and diets are critical for maintenance of healthy individuals. The natural diet of elephants has been extensively documented; free ranging elephants can be highly selective feeders or described as generalized herbivores, with diets varying according to habitat and seasonality (Dierenfeld, 1994, 2006). Spending 50 to 80% of the day feeding, both species are reported as consuming both monocots (grazers) and dicots (browsers), depending on the study, locale, and season; bark and fruits can also comprise a significant portion of native

diets. Nutritional summaries suggest that natural diet items contain moderate protein levels (typically, 8 to 13% of dry matter (DM), but ranging from 2 to 26%), high fiber concentrations (up to 82% NDF), and variable mineral content (Katole et al., 2014; Hatt and Clauss, 2006; Ullrey et al. 1997). Surveys of diets fed to elephants in US (Ange et al. 2001) and European (British and Irish Survey, 2001 unpubl; Nijboer and Casteleijn, 2002 unpubl) zoos, and two Thai captive facilities (Romain et al. 2014) documented 25 to 100 kg of dietary DM consumed per day (0.7-2.9% of body weights). DM digestibility coefficients range widely in both natural and captive diets – from approximately 30 to 80%, with grasses ~50% digestible, and legume forages, ~60% (Clauss et al., 2003; Das et al., 2015). To date, no evaluation of the diets offered to the elephants in Brazilian zoos has been published, thus, the zoo nutritionists can only utilize reference values established with animals maintained in different environmental conditions compared with those found in Brazil, and/or values based on extrapolations mainly with domestic horses, another large hindgut fermenter (Dierenfeld, 1994; Ullrey et al., 1997). Currently, 24 elephants are kept in Brazilian zoos, 7 African elephants (*Loxodonta sp.*) and 17 Asian (*Elephas maximus*), distributed across 11 zoos, (SZB, unpublished). The origin of those animals is varied, although most came from circuses, where they have been kept since a young age. Early diet history is unknown during this crucial stage of life, but we believe, based on verbal reports provided by old keepers, that diets consisted of: sugarcane (*Saccharum officinarum*), alfalfa hay (*Medicago sativa*), mixed fruits, and commercial horse feed of unspecified ratios. This paper aims to summarize data from diets offered to elephants in Brazilian zoos, evaluate nutritional profiles, make recommendations for possible changes indicated, and aim towards standardized diet recommendations within the country's zoological community.

## **Materials and Methods**

### ***Data Collection***

In November 2014, after a captive elephant management workshop attended by representatives of Brazilian zoos holding elephants, the need to evaluate diet quality was recognized. Each facility committed to send their diet record sheet for analysis to the Nutrition Working Group of the Brazilian Society of Zoos and Aquarium (SBZ). The nutritional composition of the items used in the diets was obtained from three national databases: the Brazilian Table of Food Composition TACO, 4<sup>th</sup> ed. (2011) was used for fruits and vegetables, the Brazilian Tables for Poultry and Swine, 3<sup>rd</sup> ed. (2011) was used for agricultural by-products, along with the online platform CQBAL 3.0 (2015), whereas label guaranteed analysis values were utilized for commercial foods; all data were entered into Zootrition® software (version 2.7, St. Louis, MO) for diet analysis.

### ***Animals***

Of 11 zoos that house elephants in Brazil, dietary information (ingredients and amounts offered) was obtained from 7 facilities, totaling 4 African elephants, 2 male and 2 female, and 12 Asian elephants, 1 male and 11 female (57% and 66% of the country's total individuals, respectively). All were adult animals, with ages ranging from ~20 to ~65 years. Actual or estimated body weights from individuals are found in Table 1. Of respondent zoos, only four provided actual animal weights; for the other individuals, estimated weights were based on photos and average species weight ranges (2500 – 3500 kg for Asian elephants and 4200 – 6000 kg for Africans). The daily energy requirements for adult maintenance (kcal/day) were estimated as [0.75 (143

kcal DE/BW<sup>0.75</sup> ]] from the equation suggested by Clauss et al. (2005) and used by Das et al. (2015), with a correction for reduced activity of the Brazilian elephants.

## Results

### ***Ingredients and Diets***

***Fruits and Vegetables:*** Thirteen different produce items were fed in varying quantities including cabbage, carrots, beets, pumpkin, sweet potato, corn on the cob, tomato, yucca, apples, bananas, oranges, papaya and watermelon. Amounts fed in the 7 facilities ranged from 0 to 58 kg/day/animal, averaging  $27.7 \pm 20.8$  kg (fresh weights) or  $4.8 \pm 3.6$  kg DM. Most popular items were bananas ranging from 0.1 to 2.3 kg DM (6 zoos), apples (0.1 – 0.8 kg DM) and papaya (0.1 – 1.8 kg DM) (5 zoos) and carrots (0.1 – 0.6 kg DM) (4 zoos).

***Forages:*** Nine forages were utilized in the 7 zoos, including fresh elephant grass (*Pennisetum purpureum*; n=7 facilities), alfalfa hay (*Medicago sativa*; n=6), sugar cane (*Saccharum officinarum*; n=3), sugar cane leaves only (canes used for juice extraction) (n=2) and 1 facility each for fresh cut catalonha (*Cichorium intybus*), fresh corn stalks (*Zea mays*) or corn silage, fresh bristle oat grass (*Avena strigosa*), and Tifton 85 hay (*Cynodon* spp.). Total forage offered daily averaged  $124.1 \pm 42.0$  kg, or approximately  $41.3 \pm 13.5$  kg DM. Nutrient concentrations of forages used are found in Table 2.

***Concentrates:*** Five different commercial equine products were used across 6 facilities; one fed no concentrate pellets. The average amount offered per elephant per day was  $7.7 \pm 5.2$  kg ( $6.7 \pm 4.5$  kg DM). Nutrient concentrations of concentrates used are found in Table 3.

Diets for the various zoos comprised (average per animal, as-fed basis offered):

Zoo 1 – 78 kg forage (30 kg fresh sugar cane leaves, 24 kg alfalfa hay, 12 kg Tifton 85 hay, and 12 kg sugarcane), 58 kg mixed fruits and vegetables, and 4 kg equine pellets

Zoo 2 – 107 kg forage (90 kg fresh elephant grass, 17 kg alfalfa hay), 21 kg mixed vegetables and fruits, and 6 kg equine pellets

Zoo 3 – 205 kg forage (78 kg fresh elephant grass, 66 kg fresh sugar cane leaves, 48 kg fresh sugarcane, 13 kg alfalfa hay), 10 kg mixed vegetables and fruits, and 1.8 kg equine pellets

Zoo 4 – 100 kg forage (60 kg fresh elephant grass, 40 kg alfalfa hay), 12.8 kg mixed vegetables and fruits

Zoo 5 – 107.5 kg forage (100 kg fresh elephant grass, 5 kg alfalfa hay, 2.5 kg sugar cane), 50 kg mixed vegetables and fruits, and 10 kg equine pellets

Zoo 6 – 120 kg forage (72 kg elephant grass, 24 kg fresh bristle oat grass, 24 fresh corn plant), 14.5 kg mixed vegetables and fruits, 16.5 kg equine pellets

Zoo 7 – 151.2 kg forage (94.4 kg elephant grass, 22.8 sugar cane, 20 kg maize silage, 12 kg alfalfa hay, 2 kg catalonha), and 8 kg equine pellets

Amounts of food offered, both as-fed and on a dry matter basis, are displayed in Table 4. Dry matter offered ranged from 41.7 to 67.1 kg DM/d, averaging  $51.3 \pm 8.6$  kg /d divided into 2 – 3 feeding times. Some zoos reported the use of equine trace mineral (TM) supplementation, but none provided the nutrient composition. Water was available ad libitum, and equine TM is used according to the manufacturer's recommendation for equines. No facility reported the use of plain salt.

### ***Energy***

The average amount of digestible energy (DE) offered to the animals was  $98,824 \pm 17,116$  kcal DE/d considering the following digestibility coefficients:

Digestible Energy values were calculated for fruits and vegetables, and pelleted horse feeds, by multiplying Gross Energy (GE) by 0.8. For Forages, different digestibility factors were used: for catalonha,  $DE = 0.80 \times GE$ ; corn silage,  $DE = 0.40 \times GE$ ; alfalfa hay,  $DE = 0.46 \times GE$ ; sugar cane leaves,  $DE = 0.42 \times GE$ ; oat grass,  $DE = 0.55 \times GE$ ; ; corn plant,  $DE = 0.53 \times GE$ ; Tifton hay,  $DE = 0.56 \times GE$ ; elephant grass,  $DE = 0.32 \times GE$ ; ; sugar cane,  $DE = 0.54 \times GE$  (DE values from CQBAL, 2015; Figueiredo, 1999; NRC, 2007). Estimated energy requirements, based on body weights can be found in Table 1, along with calculated calories (both Gross and Digestible) provided by the provisioned diets.

Energy concentration, fiber fractions, proximate composition, and Ca and P calculated in the diets are found in Table 5. Mean values of various fiber fractions calculated, on a DM basis, include:  $27.6 \pm 4.0$  (% crude fiber),  $33.1 \pm 4.2$  (% ADF),  $48.8 \pm 5.5$  (% NDF),  $23.1 \pm 4.8$  (% cellulose) and  $5.8 \pm 1.7$  (% lignin). These values are more descriptive of grasses (monocots) compared with browses or dicots, yet fiber content appears to be low when compared to values that have been reported from forages consumed by free-ranging elephants (NDF levels up to 82% (Das et al., 2015). Of note, water soluble carbohydrates that could be quantified for some ingredients (and would generally be highly digestible) ranged from ~10 to 50% of DM, depending on the facility.

### ***Protein***

Most zoos fed diets with higher protein content ( $10.9 \pm 2.4\%$  of DM) than necessary for maintenance requirements of adult elephants (~6 to 8% of DM; Das et al., 2015; Ullrey et al. 1997), with values ranging from 7.6 to 15.4% of DM. These high values are attributed to the amount of concentrate fed (1.8 to 16.5 kg of fresh matter per individual per day), which provided ~4 to 53% of total dietary crude protein, as well as provision of the high-protein (18% CP) alfalfa hay (4.5 to 35.6 kg DM/d).

### ***Minerals***

Due to lack of information on mineral content of the commercial feeds, trace minerals in forages, and especially lack of data on any equine mineral supplements used, Ca and P were the only minerals evaluated in this initial diet analysis. The average calcium content of the diets ( $0.7 \pm 0.2\%$ ) was higher than minimum dietary recommendations, whereas the average phosphorus content of the diets ( $0.2 \pm 0.05\%$ ) was similar to suggested values for captive elephants (Ullrey et

al., 1997). However, the Ca:P ratio, was 3.2:1, higher than that recommended of 1.5:1, due primarily to the alfalfa component (21 to 90% of Ca supplied from the alfalfa).

### ***Discussion***

Most animals appeared to be overfed, both in quantity but also in some quality parameters (calorie, protein). Numerous studies document DM intake in elephants ranging from about 1.1 to 1.5, up to 1.9% of body weight (summarized in Dierenfeld, 2006; Hatt and Clauss, 2006; Ullrey et al., 1997). Animals in this survey were offered diets with DM amounts ranging from 0.8 to 2.7% of body weights (average 1.3 to 1.7%), thus the possibility of overconsumption and / or wastage of food was high for all facilities, with the exception of one institution (Zoo 2). More importantly, all zoos provided considerably more potential digestible energy for animals than needs estimated by prediction equations for maintenance (110% to 280%), with higher amounts provided to Asian elephants than Africans, in general. These high energy values offered can be attributed to excessive amounts of highly digestible ingredients (fruits and vegetables as well as concentrates), contributing 20% (fruits and vegetables) to as much as 33% (concentrates) of dietary DM calories. Further, these percentages may underestimate the contribution from highly digestible diet ingredients. As the fruit, vegetables, and concentrates are often highly preferred diet items, they can provide a disproportionate amount of total calories ingested by the elephants. Obesity is a documented health problem of captive elephants (Hatt and Class, 2006; Das et al., 2015) that can also negatively impact joint health and reproduction. All animals in this Brazilian survey were considered overconditioned (unpublished); an initial recommendation to address this issue, supported by this survey, was to reduce total amounts of food offered, but to particularly control or minimize the concentrate portion(s) fed. One Brazilian zoo feeds no concentrate, another feeds no fruits or vegetables, to elephants with no obvious negative outcomes. The zoo that fed no fruits or vegetables uses corn silage that contained a starch concentration of 22% DM; source of calories could also impact metabolism and body condition, as has been previously documented in elephants (Clauss et al., 2003; Das et al., 2015).

Zoos 1, 3, 5 and 7 reported sugarcane as part of the diet, although amounts of fresh cane fed varied radically from 2.5 to 48 kg per animal. Diets in these zoos analyzed with an average sugar content of  $4.9 \pm 2.5\%$ , compared with an average  $1.5 \pm 0.4\%$  sugar for those without sugarcane in elephants' diets. These high sugar levels (and highly available calories) may favor obesity, particularly in elephants that lead a sedentary life. Because sugarcane is common in Brazil, some zoos cultivate fields of the crop strictly for feeding their elephants, thus elimination or changing that crop to different forage may not be an immediate option. A practical alternative for these facilities may be to utilize sugarcane bagasse, a by-product from the sugarcane juice extraction, in the elephant feeding programs rather than the intact canes or whole plant. Comparing the two, sugarcane bagasse contains higher levels of fiber, 44.1 vs. 26.8% crude fiber, 85.7 vs. 54.3% NDF, and 59.0 vs 33.5% (all DM basis) than whole sugarcane, as well as considerably lower levels of water soluble carbohydrates (0.8 vs 35.0%). Thus processed cane bagasse may elevate dietary fiber levels, decrease digestibility, and is also much more economic than the sugarcane. We recommend that cane bagasse (estimated 27% digestibility) and/or leaves, rather than whole sugarcane fractions, be incorporated as forage sources in Brazilian zoo elephant diets. Elephant grass, at 32% digestibility, could also be used to replace some of the higher quality forages (i.e. sugarcane, Tifton and oat hays, alfalfa, and especially catalonha) to decrease dietary calorie concentrations for captive elephants.

Regarding dietary protein concentrations, the analyses reported may underestimate actual intakes, as the equine concentrate pellets (containing protein levels ranging from 12 to 17% DM) were consumed in entirety, while forages were not. Although the relatively high protein levels quantified here do not appear to cause problems for the adult animals at maintenance, and can certainly be necessary to meet needs for growth or reproduction (Das et al., 2015; Ullrey et al. 1997), they can be expensive to overfeed. If protein needs can be met by available forages (see Table 3) adjustment of diets to minimize pellets and meet the protein requirements with forage is suggested. Low protein forages (i.e. all sugar cane fractions, elephant grass and corn plants) can be blended with higher CP forages such as catalonha or alfalfa to meet protein needs.

The high Ca:P ratio found in the diet can be attributed to the high concentration of calcium found in alfalfa hay (1.3% DM), however there is no evidence that this increased amount of calcium, and consequent high Ca:P ratio is harmful to elephants. Clearly more detail is needed for other minerals in the diets of these animals for optimal health and nutritional assessment, and is recommended for future action.

Soon after the initial diet analysis, zoos were provided reports with suggestions to improve nutritional balance and minimize waste. Zoo 3 had 2 animals with clear signs of obesity (body condition scores 8 and 7 in a 1-9 scale (Wemmer et al., 2006)). They offered to immediately make changes in their diets in order to improve the quality of life of the animals. Following implementation of proposed changes in the diet (Tables 6-7), the DM intake was reduced from 2.2 to 0.7 %BW (animal 1) and from 2.7 to 0.8 %BW (animal 2). Energy amounts were reduced to approximately 1/3 the original levels, from ~122,000 kcal to ~37,000 kcal/day for animals weighing between 2500 to 3000 kg (with an estimated energy requirement of ~38,000 to ~43,000 kcal/day), corresponding to approximately 90-100% of estimated energy needs., and crude protein concentration was increased from 7.6 to 9% DM. Also, a conditioning program was implemented with daily training sections. After 3 months, an obvious reduction in body condition scores can be seen in Figures 1 and 2. The results obtained by zoo 3 are considered satisfactory, and they can be regarded as a reference so that other elephants in the same obesity conditions may gradually improve body condition. As with all herbivores, diet changes should be made slowly (over weeks to months) and, in the case of dramatic reduction in quantities, it is essential that the nutritional profile of the total diet be assessed to ensure that known or estimated nutritional needs are being met.

### **Initial Recommendations for Brazilian Zoo Elephant Diets**

1. Maintenance diets should be formulated to provide 1-1.5% of body weight as dry matter intake. Lower quantities, or poorer quality ingredients, are required for weight loss diets.
2. Energy; pelleted concentrate feeds and fruits and vegetable amounts can be minimized and carefully controlled to provide no more than ~10% of calculated calorie needs and optimize nutrient balance as well as feeding economics.
3. Nutrient target concentrations should be developed as per recommended by the AZA Nutrition Advisory Group, using equine requirements as primary guidelines.
4. The use of whole sugar cane in feeding programs, with its high calorie content from readily available sugars, is discouraged. Rather, cane bagasse, following juice extraction, can be offered to elephants as a fiber source, in addition to other forages to balance

nutrients. Elephant grass is particularly suggested as a suitable and economic forage, but nutrient quality must be monitored and maintained.

5. More detailed analyses of mineral content of commercial equine feeds, forages, and especially mineral supplements fed to elephants in Brazilian zoos is needed to better analyze, balance, and optimize feeding programs for these species.

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**Table 1.** Estimated daily maintenance energy requirements (MER, kcal) of elephants in 7 Brazilian zoological facilities, with calculated Gross Energy (GE) and Digestible Energy (DE) values provided by diets.

	<b>Unit</b>	<b>Zoo 1</b>	<b>Zoo 2</b>	<b>Zoo 3</b>	<b>Zoo 4</b>	<b>Zoo 5</b>	<b>Zoo 6</b>	<b>Zoo 7</b>
<b>Weight Animal 1</b>	kg	3.000	6.000	3.000	3.500	3.000	3.000	3.800
<b>Maint Energy Reqt</b>	Kcal DE/d	43.475	73.116	43.475	48.803	43.475	43.475	51.908
<b>Calc Dietary Energy</b>	Kcal GE/d	220.892	187.250	279.585	207.704	163.060	194.765	204.750
<b>Calc Dietary Energy</b>	Kcal DE/d	117.113	90.088	122.093	89.249	80.628	107.475	91.046
<b>Weight Animal 2</b>	kg	3.000	6.000	2.500	2.600	2.500		3.800
<b>Maint Energy Reqt</b>	Kcal DE/d	43.475	73.116	37.919	39.051	37.919		51.908
<b>Calc Dietary Energy</b>	Kcal GE/d	220.892	187.250	279.585	207.704	163.060		204.750
<b>Calc Dietary Energy</b>	Kcal DE/d	117.113	90.088	122.093	89.249	80.628		91.046
<b>Weight Animal 3</b>	kg	3.000	5.000					4.200
<b>Maint Energy Reqt</b>	Kcal DE/d	43.475	63.771					55.954
<b>Calc Dietary Energy</b>	Kcal GE/d	165.669	146.726					219.927
<b>Calc Dietary Energy</b>	Kcal DE/d	87.835	70.592					97.794

**Table 2.** Nutritional composition of forages fed to elephants in Brazilian Zoos.

	Unit	Alfalfa Hay	<i>Avena strigosa</i>	Sugar cane	Elephant Grass	Catalonha	Corn stalks	Sugar cane leaves only	Corn silage	Tifton Hay
<b>Dry Matter</b>	%	89	17	28	21	9	33	35	31	89
<b>Gross Energy</b>	kcal/g	4.22	4.10	4.13	4.12	2.67	4.27	4.29	4.33	4.29
Carbohydrates										
<b>ADF</b>	%	37.52	31.00	33.52	46.24		28.05	41.31	30.67	39.32
<b>Cellulose</b>	%	29.42		28.37	38.00		25.92		26.91	32.03
<b>Crude Fiber</b>	%	29.36	31.50	26.79	35.75		25.02	43.70	24.90	32.34
<b>Lignin</b>	%	9.74	4.50	5.86	7.85		4.66		4.87	5.13
<b>NDF</b>	%	46.93	54.30	54.29	76.00		55.25	54.64	54.52	77.68
<b>Starch</b>	%	4.64		4.15			6.95		22.56	1.20
<b>Sugar</b>	%			19.00						
<b>Water Soluble Carbohydrates</b>	%	69.11		35.00		53.33				6.57
Fat And Protein										
<b>Crude Fat</b>	%	2.85		1.34	2.20	3.33	2.06	2.24	2.84	1.75
<b>Crude Protein</b>	%	18.77	11.60	2.76	6.80	21.11	7.06	4.93	7.24	9.12
Ash/minerals										
<b>Ash</b>	%	9.11	3.45	3.12	9.02	14.44	4.51	6.23	5.07	7.10
<b>Calcium</b>	%	1.30	0.34	0.23	0.34	0.63	0.16	0.31	0.31	0.50
<b>Phosphorus</b>	%	0.24	0.20	0.08	0.23	0.36	0.08	0.06	0.19	0.18
<b>Ca:P</b>	Ca/P	5.42	1.70	2.88	1.48	1.78	2.00	5.17	1.63	2.78

**Table 3.** Nutritional composition of concentrates fed to elephants in Brazilian Zoos.

		<b>CRAVIL EQUINOS MANUTENÇÃO</b>	<b>GUABI NUTRIAGE 15 LAMINADOS</b>	<b>NUTRINA EQUINOS</b>	<b>PRESENCE</b>	<b>SUPRA EQUINOS</b>
<b>Dry Matter</b>	%	88	87	87	87	88
<b>Gross Energy</b>	kcal/g	3.25	3.40	2.35	3.81	3.39
<b>ADF</b>	%		10.00		11.49	
<b>Crude Fiber</b>	%	12.00	12.00	10.00	11.49	16.00
<b>Crude Fat</b>	%	3.50	4.00	2.00	4.02	2.00
<b>Crude Protein</b>	%	12.50	15.00	17.00	17.24	12.00
<b>Ash</b>	%	9.90	12.00	10.00	14.94	15.00
<b>Calcium</b>	%	1.20	1.50	1.50	1.38	2.00
<b>Copper</b>	mg/kg	12.00	3.45			
<b>Phosphorus</b>	%	0.60	0.50	0.60	0.57	0.40
<b>Ca:P</b>	Ca/P	2.00	3.00	2.50	2.40	5.00

**Table 4.** Total amounts of diet (as fed and dry matter) offered to elephants in Brazilian zoos, dry matter (DM) offered as a % of body weight.

	<b>Unit</b>	<b>Zoo 1</b>	<b>Zoo 2</b>	<b>Zoo 3</b>	<b>Zoo 4</b>	<b>Zoo 5</b>	<b>Zoo 6</b>	<b>Zoo 7</b>	<b>Average</b>	<b>SD</b>
<b>Total</b>	kg	140	134	216.8	112.8	167.5	151	159.2	154.5	32.8
<b>Dry Matter</b>	%	40.8	36.6	31	44.2	25.2	28.9	31.6	0.3	
<b>Dry Matter</b>	kg	57.1	49.0	67.2	49.9	42.2	43.7	50.3	51.3	8.5
<b>Animal 1</b>	DM%BW	1.9	0.8	2.2	1.4	1.4	1.5	1.3	1.5	
<b>Animal 2</b>	DM%BW	1.9	0.8	2.7	1.9	1.7	-	1.3	1.7	
<b>Animal 3</b>	DM%BW	1.9	0.8	-	-	-	-	1.2	1.3	

**Table 5.** Calculated composition of diets (select nutrients) fed to elephants in Brazilian Zoos. All values (except dry matter, DM) on a DM basis.

	<b>Unit</b>	<b>Zoo 1</b>	<b>Zoo 2</b>	<b>Zoo 3</b>	<b>Zoo 4</b>	<b>Zoo 5</b>	<b>Zoo 6</b>	<b>Zoo 7</b>	<b>Average</b>	<b>SD</b>
<b>Gross Energy</b>	kcal/g	3.9	3.8	4.2	4.2	3.9	4.5	4.1	4.1	0.2
<b>Digestible energy</b>	% GE	53.0%	48.1%	43.7%	43%	49.4%	55.2%	44.5%	48	
<b><u>Carbohydrates</u></b>										
<b>ADF</b>	%	31	31.3	38.77	38.45	29.98	27.77	34.22	33.1	4.24
<b>Cellulose</b>	%	18.7	23.72	20.07	30.59	22.78	17.86	28.14	23.1	4.80
<b>Crude Fiber</b>	%	27.71	23.90	34.58	30.00	24.49	23.69	29.03	27.6	3.98
<b>Lignin</b>	%	4.95	6.42	4.78	8.93	5.10	3.98	6.50	5.8	1.65
<b>NDF</b>	%	45.34	47.91	56.44	52.68	44.25	41.40	53.52	48.8	5.54
<b>Starch</b>	%	3.11	2.26	1.68	3.70	2.63	1.70	4.29	2.8	0.99
<b>Sugar</b>	%	4.62	1.87	4.04	1.17	8.37	1.40	2.41	3.4	2.55
<b>Total Dietary Fiber</b>	%	1.85	0.60	0.23	0.54	1.87	0.61	0.08	0.8	0.74
<b>Water Soluble Carbohydrates</b>	%	33.80	36.20	12.71	50.18	9.70	2.12	14.86	22.8	17.39
<b><u>Fat And Protein</u></b>										
<b>Crude Fat</b>	%	2.14	2.28	2.18	2.65	2.37	2.48	2.28	2.3	0.18
<b>Crude Protein</b>	%	11.68	11.43	7.61	15.38	9.60	10.75	9.66	10.9	2.42
<b><u>Ash/minerals</u></b>										
<b>Ash</b>	%	7.58	7.73	6.87	8.93	8.60	9.37	8.66	8.2	0.88
<b>Calcium</b>	%	0.79	0.70	0.49	1.02	0.64	0.64	0.76	0.7	0.16
<b>Copper</b>	mg/kg	0.70	0.20	0.40	0.11	1.62	0.17	0.11	0.5	0.55
<b>Iron</b>	mg/kg	2.66	1.07	49.99	0.74	4.56	0.85	1.23	8.7	18.25
<b>Manganese</b>	mg/kg	2.45	0.70	29.71	0.31	3.46	0.91	0.14	5.4	10.79
<b>Phosphorus</b>	%	0.18	0.26	0.15	0.23	0.26	0.31	0.23	0.2	0.05
<b>Potassium</b>	%	0.22	0.98	0.61	0.65	1.38	0.89	0.95	0.8	0.36
<b>Zinc</b>	mg/kg	1.79	0.46	49.89	0.44	3.24	0.53	0.20	8.1	18.47
<b>Ca:P</b>	Ca/P	4.32	2.74	3.24	4.35	2.43	2.07	3.27	3.2	0.88

**Table 6.** Estimated daily maintenance energy requirements (MER, kcal) and dry matter intakes (DMI, %BW) of elephants in Zoo 3, before and after diet changes, with calculated Gross Energy (GE) and Digestible Energy (DE) values provided by diets.

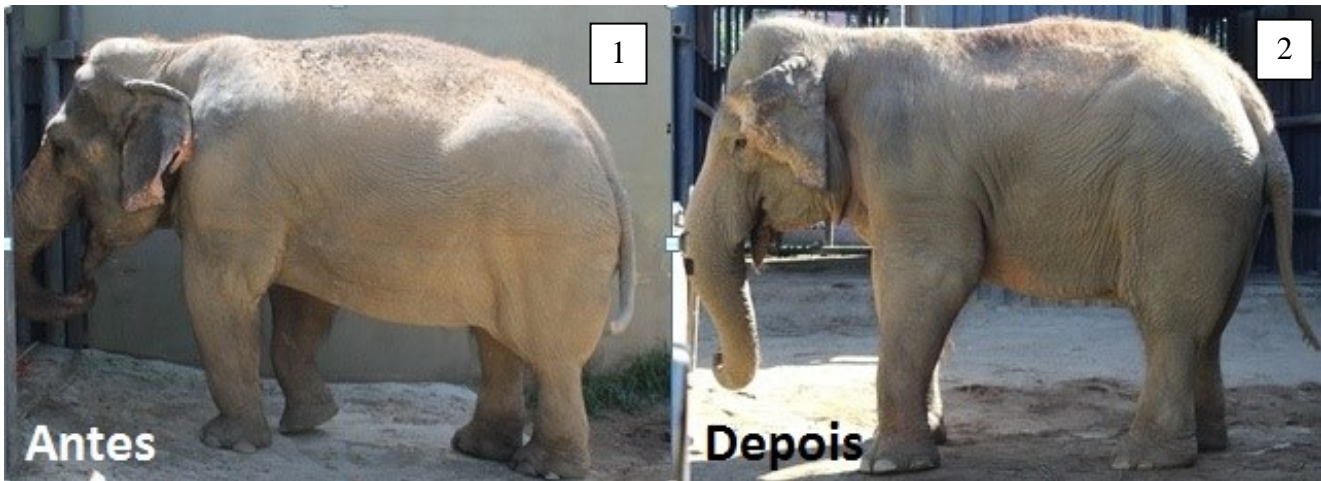
	Unit	Before diet change	After diet change
<b>Weight Animal 1</b>	kg	3000	3000
<b>DMI</b>	%BW	2.2	0.7
<b>Maint Energy Reqt</b>	kcalDE/d	43,475	43,475
<b>Calc Dietary Energy</b>	kcalGE/d	279,585	83,400
<b>Calc Dietary Energy</b>	kcalDE/d	122,093	37,682
<b>Weight Animal 2</b>	kg	2500	2500
<b>DMI</b>	%BW	2.7	0.8
<b>Maint Energy Reqt</b>	kcalDE/d	37,919	37,919
<b>Calc Dietary Energy</b>	kcalGE/d	279,585	83,400
<b>Calc Dietary Energy</b>	kcalDE/d	122,093	37,682

**Table 7.** Zoo 3 elephant diet amounts and ingredients before and after suggested changes.

	Before diet change			After diet change		
	DM (g)	As Fed (g)	% DM	DM (g)	As Fed (g)	% DM
<b>CENOURA/CARROT</b>	200	2,000	0.30%	800.00	8,000.00	3.9%
<b>ABOBORA/PUMPKIN</b>	240	2,000	0.36%	960	8,000	4.6%
<b>MAÇA FUJI, COM CASCA/APPLE IN SHELL</b>	80	500	0.12%	160	1,000	0.8%
<b>TOMATE/TOMATO</b>	100	2,000	0.15%	0	0	0.0%
<b>MAMÃO/PAPAYA</b>	120	1,000	0.18%	0	0	0.0%
<b>BANANA</b>	115	500	0.17%	230	1,000	1.1%
<b>LARANJA/ORANGE</b>	65	500	0.10%	0	0	0.0%
<b>MILHO ESPIGA/CORN COB</b>	0	0	0.00%	870	1,000	4.2%
<b>MELANCIA/WATERMELON</b>	150	1,500	0.22%	100	1,000	0.5%
<b>ALFAFA,FENO/ALFAFA HAY</b>	11,570	13,000	17.23%	3,560	4,000	17.1%
<b>PONTA DE CANA/SUGAR CANE AERIAL PART</b>	23,100	66,000	34.40%	7,000	20,000	33.7%
<b>CAPIM ELEFANTE/ELEPHANT GRASS</b>	16,380	78,000	24.40%	6,300	30,000	30.3%
<b>CANA/SUGAR CANE</b>	13,440	48,000	20.02%	0	0	0.0%
<b>CRAVIL EQUINOS MANUTENÇÃO</b>	1,584	1,800	2.36%	780	1,000	3.8%
<b>Total (g)</b>	67,144	216,800		20,760	75,000	



**Figure 1.** Body score estimative before diet change (1) and after (2) to animal 1 from zoo 3.



**Figure 2.** Body score estimative before diet change (1) and after (2) to animal 2 from zoo 3.