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RESEARCH ARTICLE

Analysis of nutrient components of food for Asian Elephants in the wild and in captivity

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Abstract Thirty-seven wild plants as food for Asian elephants in the field in Simao, Yunnan province, China and five cultivated plants as food for captive elephants in the Beijing Zoo were collected and analyzed for their main nutrient components. Protein, fat, fiber, dry material, ash as well as major microelements: calcium, kalium, zincum, sodium in the food were analyzed by standard methodology. No significant differences were found between the wild plants taken in the field and forage provided in captivity. However, the calcium content in the forage is significantly less than the average of those in the wild plants. It is suggested that the increase in calcium intake may contribute to the relief of low plasma calcium diseases of elephants in captivity.

Keywords Asian Elephant, nutrition analysis, microelements

1 Introduction

The Asian elephant (*Elephas maximus*) is ranked as an endangered species by IUCN, with an estimated population of about 34,000–54,000 around the world (Santiapillai and Jackson, 1990; Wang, 1998). The current refuge of the wild Asian Elephants in China is the south and southwest of Yunnan province, and the their population is about 200–250 (Wang, 1998; Zhang and Wang, 2003).

Although as much as 75 plant species can be consumed by the Asian Elephants living in tropical regions, only certain kinds are specially preferred (Shoshani and Eisenberg, 1982). Leaves, barks, twigs, herbs, roots, corms, flowers, fruits, etc. can be eaten by Asian elephants (McKay, 1973; Nowak, 1995; Sukumar and Ramesh, 1995). An adult Asian elephant consumes forage between 150 and 350 kg in wet weight per day due to the low nutrition value of most food (Dougall, 1964; Eisenberg, 1981; Hanks, 1979; Macdonald, 1984; Shoshani and Eisenberg, 1982). This means that the amount of dry matter consumed is equal to 1.5%–1.9% of body weight.

In Europe, investigations on captive Asian elephants' forage in many zoos were conducted by the European Association of Zoos and Aquaria, and they found that the imbalance of nutrition in the forage was very common. These may cause many healthy problems, and even make the elephants die.

In China, however, no research has focused on the analysis of the dietary nutrient for Asian elephants and little information of captive elephants' dietary nutrition is available in the country. The present study analyzed the nutrient components of the food for Asian elephants both in the wild and captivity, and we hope that the results can contribute to the welfare of captive Asian elephants by adjusting their diet.

2 Materials and methods

2.1 Materials

Thirty-seven wild plants which are eaten by Asian elephants in the field in Simao, and five cultivated plant species fed to captive elephants in the Beijing Zoo were collected (Tables 1 and 2). Five hundred grams of each was made into dry powder by drying at 70°C or air-drying.

2.2 Determination index

Proximate composition of dry matter (DM), crude protein (CP), ether extraction (EE), crude fiber (CF), crude ash (CA) and eight mineral elements (Zn, Fe, Mg, Ca, Na, K, S) were determined in all samples.

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Table 1 Nutrient composition of elephants' wild food

Plant species		W/%				
		DM	CP	EE	CF	CA
Moraceae	*Bauhinia acuminate*	90.99	17.94	1.84	10.31	19.09
	Ficus cyrtophylla	93.70	16.47	2.26	18.84	16.13
	F. racemosa	90.88	15.18	1.95	13.95	14.41
	F. Hispida	90.33	13.14	1.72	17.88	19.22
	F. hirta	93.28	10.95	1.69	19.79	18.45
	F. subincisa	93.73	9.38	2.86	27.31	13.99
	F. nuobuo	91.57	7.88	2.79	14.48	13.10
Gramineae	*Arundo donax*	95.73	14.25	2.11	25.13	9.49
	Thysanolaena maxima	92.63	11.94	1.59	31.97	9.14
	Pleiolastus amarus	95.03	11.55	1.94	28.57	11.92
	Triticum Sestivum	93.08	9.97	2.12	24.67	5.00
	Dendrocalamus hamiltonii	95.10	8.01	1.36	38.82	8.88
	Digitaria sericea	95.75	7.85	1.23	33.64	11.35
	Microsteguim Cihatum	95.80	3.59	1.94	39.29	3.89
Leguminosae	*Acacia megaladena*	92.42	19.68	1.94	25.95	7.97
	Radix Puerariae (leaves and branches)	93.13	17.19	0.68	30.84	10.35
	Radix Puerariae (roots)	91.86	16.55	0.47	6.49	6.53
	Campylotropis harmsii	94.10	12.86	2.59	27.86	4.34
Musaceae	*Musa acuminata*	94.97	3.70	1.94	23.76	12.98
	Ensete glaucum	95.09	5.65	1.47	16.02	10.87
Urticaceae	*Dead Nettle*	94.94	11.90	0.53	35.65	13.49
	Debregeasia longifolia	91.42	18.65	2.86	10.74	19.56
Juglandaceae	*Engelhardtia spicata*	92.06	1.91	0.47	20.89	4.67
	E. serrata	92.17	2.11	0.75	31.47	3.13
Euphorbiaceae	*Mallotus tetracvoccus*	95.27	2.45	1.49	31.40	16.70
Gleicheniaceae	*Dicranopteris dichotoma*	95.50	0.95	1.07	58.68	2.10
Rosaceae	*Rubus multibrascteaus*	93.32	11.78	2.33	28.81	7.51
Fagaceae	*Castanopsis hystrix* (branches)	93.33	1.23	0.60	42.54	9.86
	Castanopsis hystrix (roots)	93.78	4.19	0.84	30.47	2.26
	Lithocarpus grandifolius	92.39	2.41	1.38	37.56	3.79
Anacardiaceae	*Rhus chinensis*	93.79	7.94	9.34	18.97	9.03
Cyqeacae	*Scleria levis*	96.72	1.42	0.84	40.98	4.51
Caesalpiniaceae	*Bauhinia acuminate*	94.56	14.46	1.36	34.06	7.26
Hypoxidaceae	*Curculigo capitullata*	93.32	13.59	1.13	33.46	11.48
Palmae	*Wallichia chinensis*	93.99	11.46	1.91	28.22	7.60
Stachys	*Stachyphrynium Sinensis*	93.17	12.26	0.83	28.26	9.94

W: weight percentage; DM: dry matter; CP: crude protein; EE: ether extraction; CF: crude fiber; CA: crude ash.

2.3 Methods

Crude protein was analyzed using the Kjeldahl method, crude fat by ether extraction and fiber by drying and ashing after extraction with 0.5 M H_2SO_4 and 1.0 M NaOH. Dry matter was determined after the samples were dried to constant weight. Ash content was determined after 12 h at 550°C in a muffle furnace. Mineral elements were determined using ULTIMA induction coupler plasma atomic emission spectrograph of the JY company, France (Gu, 1990; Yang, 1993).

3 Results

3.1 Proximate composition of nutrient components of food

Table 1 showed the proximate composition of nutrient components of wild food. The W(CP) of Maraceae, Gramineae, Leguminosae, Musaceae, Urticaceae, Juglandaceae and other 12 species of 12 families were: 7.88%–17.94%, 3.59%–14.25%, 12.86%–19.68%, 3.70%–5.65%, 11.90%–18.65%, 0.47%–0.75% and 0.95%–14.46%, respectively. The W(EE)

Table 2 Nutrient composition of elephants' forage in the Beijing Zoo

Plant species	W(weight fraction)/%				
	DM	CP	EE	CF	CA
Medicago spp.	94.82	20.67	2.30	26.97	9.39
Phragmites australis	93.02	14.52	1.66	30.37	10.51
Sorghum Sudan	88.15	8.91	2.87	28.11	6.94
Oryza sativa	86.53	8.11	2.05	26.24	5.68
Pleioblastus spp.(leaves)	93.58	12.61	3.27	25.04	12.90
Pleioblastus spp.(stems)	89.41	2.22	0.52	41.22	1.87
pellets	85.55	17.21	1.46	4.43	7.53

W: weight percentage; DM: dry matter; CP: crude protein; EE: ether extraction; CF: crude fiber; CA: crude ash.

of Maraceae, Gramineae, Leguminosae, Musaceae, Urticaceae, Juglandaceae, Anacardiaceae Rhus chinensis and other 11 species of 11 families were: 1.69%–2.86%, 1.23%–2.12%, 0.47%–2.59%, 1.47%–1.94%, 0.53%–2.86%, 1.91%–2.11%, 9.34% and 0.95%–14.46%, respectively. The W(CF) of Maraceae, Gramineae, Leguminosae, Musaceae, Urticaceae, Juglandaceae and other 12 species of 12 families were: 10.31%–27.31%, 24.67%–39.29%, 6.49%–30.84%, 16.02%–23.76%, 10.74%–35.65%, 20.89%–31.47% and 18.97%–58.68%, respectively.

Table 2 showed the proximate composition of nutrient components of forage. The W(CP), W(EE), W(CF) were: 2.22%–20.67%, 0.52%–3.27%, 25.04%–41.22%, respectively. There were few differences between the forage and wild food with respect to W(CP), W(EE) and W(CF) (Table 1).

3.2 Proximate composition of mineral microelements in food

Table 3 showed content of every mineral microelement analyzed in the wild food: phosphorus (P), 111.6–3,876.0 $\mu g \cdot g^{-1}$; zinc (Zn), 4.5–57.2 $\mu g \cdot g^{-1}$ (specially, *F. hirta* 166.7 $\mu g \cdot g^{-1}$); iron (Fe), 57.7–555.0 $\mu g \cdot g^{-1}$ (specially, *F. racemosa* 1049.0 $\mu g \cdot g^{-1}$); magnesium (Mg), 309.9–5,211.0 $\mu g \cdot g^{-1}$ (specially, Bauhinia acuminate 6,990.0 $\mu g \cdot g^{-1}$); calcium (Ca), 318.7–37,500.0 $\mu g \cdot g^{-1}$ (specially, Bauhinia acuminate 49,530.0 $\mu g \cdot g^{-1}$, debregeasia longifolia 51,050.0 $\mu g \cdot g^{-1}$ and mallotus tetracvoccus 59,660.0 $\mu g \cdot g^{-1}$); natrium (Na), 13.8–276.2 $\mu g \cdot g^{-1}$; kalium (K), 1,291.0–13,220.0 $\mu g \cdot g^{-1}$ (specially, Curculigo capitullata 17,740.0 $\mu g \cdot g^{-1}$, Ensete glaucum 28,030.0 $\mu g \cdot g^{-1}$ and Musa acuminate 30,540.0 $\mu g \cdot g^{-1}$); sodium (S), 177.6–2,519.0 $\mu g \cdot g^{-1}$ (specially, Arundo donax 3,682.0 $\mu g \cdot g^{-1}$).

Table 4 showed the content of every mineral microelement in forage: phosphorus (P), 934.7–3,745.0 $\mu g \cdot g^{-1}$; zinc (Zn), 8.2–46.4 $\mu g \cdot g^{-1}$; iron (Fe), 70.1–665.7 $\mu g \cdot g^{-1}$; magnesium (Mg), 496.2–4,711.0 $\mu g \cdot g^{-1}$; calcium (Ca), 276.5–5,512.0 $\mu g \cdot g^{-1}$ (specially, *Medicago spp.* 22,580.0 $\mu g \cdot g^{-1}$); natrium (Na), 115.6–557.1 $\mu g \cdot g^{-1}$ (specially, *Medicago spp.* 2,916.0 $\mu g \cdot g^{-1}$ and *Oryza sativa* 3,068.0 $\mu g \cdot g^{-1}$); kalium (K), 2,466.0–11,770.0 $\mu g \cdot g^{-1}$; sodium (S), 1,452.0–2,942.0 $\mu g \cdot g^{-1}$ (specially, *Pleioblastus spp.* 285.1 $\mu g \cdot g^{-1}$). For pellets, the content of most elements were accordant with those in forage, except for calcium, natrium in excess. One issue that should be given attention was the calcium in forage which is lower than that in most wild food.

4 Discussion

Results showed that there were few differences in the proximate composition and mineral microelements of the wild food and forage in the Beijing Zoo. However, there were still some issues which we should pay attention to, such as the low content of calcium in forage. It is wildly acknowledged that the deficiency in calcium could cause muscle twitch, body ankylosis, eye jumping, partial paralysis of trunk as well as anesthetization of the pharynx (Kloes and Lang, 1982). So additional calcium or calcium-rich food may improve the health of captive elephants.

Seven plant species (*Mallotus tetracvoccus*, *Thysanolaena maxima*, *F. nuobuo*, *Wallichia chinensis*, *Campylotropis harmsii*), which were found as the elephants' main food in the wild (Zhang and Wang, 2003), were analyzed as well as the other 30 plant species in the present study. Except for *Mallotus tetracvoccus* 2.45% and *Musa acuminate* 3.70%, the W(CP) of the other main food is 7.88%–12.86%, higher than the other 30 plant species collected. However, C(K) of *Musa acuminate* and C(Ca) of *Mallotus tetracvoccus* are much higher than the other 30 plant species. The results might explain why wild elephants prefer seven main food over the others.

The European Association of Zoos and Aquaria found that in the zoos they investigated, the level of W(EE) in 86.8% forages was above the recommended level. Meanwhile, the level of C(Zn) in 90.8% and the level of C(Fe) in 82.9% forages were below the recommended level. The deficiency in iron can cause anaemia as well as symptoms of emaciation, low pulse, catarrh and dropsy (Kloes and Lang, 1982). Thus, we suggest that a similar investigation should be done in zoos in China to confirm the issues and thereby make possible adjustments based on the results.

There is still much work needed to establish the relationship between food selection and the nutrition value of food. The results may help improve the feeding techniques used for captive elephants. The problems that are needed to be solved in further studies are described below:

1) is the order in the consumption of different plants by elephants relative to the protein content, or other components in food?

2) are there great temporospatial changes in the nutrient content of any given plant?

3) how to evaluate the palatability of any given plant?

To solve them, issues such as the following could be taken into consideration: first, determine the order of the consumption of different plants through field observation, and analyze their content for nutrient components and microelements to explain the order; second, analyze the temporospatial changes

Table 3 Mineral composition of elephants' wild food

Plant species		C/(μg·g^{-1})							
		P	Zn	Fe	Mg	Ca	Na	K	S
Moraceae	*Bauhinia acuminate*	2,404	34.70	804.0	6,990	49,530	73.97	7,325	2,245
	Ficus cyrtophylla	1,343	21.03	205.6	2,739	30,480	22.92	10,460	1,599
	F. racemosa	2,107	53.12	1,049.0	3,297	26,810	187.20	12,350	1,800
	F. Hispida	3,155	23.41	230.6	3,508	30,090	269.80	12,170	2,519
	F. hirta	1,798	166.70	309.0	4,365	37,500	19.57	8,012	1,948
	F. subincisa	1,160	26.44	224.8	3,752	21,600	76.94	8,919	1,288
	F. nuobuo	1,052	25.74	153.6	5,211	23,280	14.29	5,040	1,722
Gramineae	*Arundo donax*	1,684	13.90	209.6	987	4,518	16.95	9,508	3,682
	Thysanolaena maxima	2,025	31.07	275.0	1,796	3,960	30.24	10,380	2,016
	Pleiolastus amarus	995	35.56	177.5	1,052	3,234	13.82	5,661	1,615
	Triticum Sestivum	1,648	23.14	126.2	1,524	2,768	276.20	6,296	2,262
	Dendrocalamus hamiltonii	1,144	24.86	178.1	1,622	2,071	27.79	7,022	1,192
	Digitaria sericea	3,876	52.46	449.0	1,960	3,707	34.11	8,146	1,136
	Microsteguim Cihatum	592	38.35	132.1	1,116	1,934	14.39	3,769	568
Leguminosae	*Acacia megaladena*	2,605	24.98	469.8	3,364	8,507	55.82	10,560	1,763
	Radix Puerariae (leaves and branches)	2,210	27.23	200.5	2,722	23,270	56.74	8,650	1,330
	Radix Puerariae (roots)	3,436	57.17	496.2	2,052	3,609	262.30	12,920	1,152
	Campylotropis harmsii	1,023	27.49	283.6	1,784	5,115	22.17	5,796	904
Musaceae	*Musa acuminata*	1,119	7.40	57.7	881	2,686	69.55	28,030	544
	Ensete glaucum	1,015	8.31	95.7	1,892	4,866	52.30	30,540	486
Urticaceae	*Dead Nettle*	1,842	31.92	288.3	4,606	24,740	242.50	11,820	1,401
	Debregeasia longifolia	1,980	30.18	753.4	4,031	51,050	41.80	8,112	2,131
Juglandaceae	*Engelhardtia spicata*	255	14.16	555.0	2,004	7,200	191.40	1,945	250
	E. serrata	263	7.11	392.7	1,215	5,348	113.10	1,291	262
Euphorbiaceae	*Mallotus tetracvoccus*	514	10.52	106.7	765	59,660	69.22	6,102	1,859
Dicranopteris dichotoma	*Dicranopteris dichotoma*	112	5.44	288.4	310	319	24.39	3,011	178
Rubus multibrascteaus	*Rubus multibrascteaus*	1,746	31.20	482.4	4,138	8,821	28.48	9,805	1,347
Fagaceae	*Castanopsis hystrix* (branches)	325	4.48	163.2	608	4,652	235.30	1,499	258
	Castanopsis hystrix (roots)	391	10.76	401.9	1,402	2,553	124.50	1,870	751
	Lithocarpus grandifolius	251	5.05	470.3	915	5,193	26.27	1,818	298
Anacardiaceae	*Rhus chinensis*	1,300	15.85	182.7	2,479	19,610	196.10	8,380	883
Cyqeacae	*Scleria levis*	416	11.16	101.0	645	976	18.24	5,997	480
Caesalpiniaceae	*Bauhinia acuminate*	3,755	32.65	310.8	3,914	12,640	66.84	7,417	1,286
Curculigo capitullata	*Curculigo capitullata*	1,607	29.02	189.1	4,749	15,600	93.68	17,740	2,002
Wallichia chinensis	*Wallichia chinensis*	1,315	18.54	378.7	1,809	6,254	13.93	5,609	1,505
Stachys	*Stachyphrynium Sinensis*	1,683	22.07	196.7	3,114	5,765	17.07	13,220	2,222

C: concentration; P: phosphorus; Zn: zinc; Fe: iron; Mg: magnesium; Ca: calcium; Na: natrium; K: kalium; S: sodium.

Table 4 Mineral composition of elephants' forage in the Beijing Zoo

Plant species	C(content)/(μg·g^{-1})							
	P	Zn	Fe	Mg	Ca	Na	K	S
Medicago spp.	2,272	24.90	445.2	4,711	22,850	2,916.30	7,145	2,942
Phragmites australis	2,182	35.30	122.0	1,619	4,086	557.14	11,770	2,627
Sorghum Sudan	2,864	46.40	313.4	2,361	3,113	115.60	11,350	1,452
Oryza sativa	1,571	19.30	179.2	1,549	3,099	3,068.10	6,543	1,540
Pleioblastus spp. (leaves)	935	22.20	665.7	2,068	5,512	157.82	4,681	2,208
Pleioblastus spp. (stems)	3,745	8.17	70.1	496	277	169.32	2,466	285
Pellets	5,518	31.83	215.2	2,115	15,530	4,247.00	4,900	1,603

C: concentration; P: phosphorus; Zn: zinc; Fe: iron; Mg: magnesium; Ca: calcium; Na: natrium; K: kalium; S: sodium.

in the nutrient content of the food; finally, evaluate the palatability of forage. According to our experience, if an elephant was confronted with a cole, apple and carrot at the same time, it would first eat the apple, then carrot and then lastly, the cole. We also found that if any drug was asymmetrically mixed into the fodder or fruits, the elephants would refuse to eat the fodder or fruits. All these lead us to suppose that palatability can influence elephants' foraging. We also found another interesting phenomenon: elephants prefer sugarcane. This has made us to suppose that sugar content might also have a correlation with food palatability. However, no standard in food palatability is available at present making it difficult to draw a positive conclusion.

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