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Abstract: Diet and nutrition of cheetahs was evaluated through survey, in conjunction with chemical analysis of feed and plasma samples, as pan of a multidisciplinary effort to investigate underlying causes of low reproductive success in North American captive cheetah populations. Cheetahs consumed an average of 1.32  0.4 kg of food daily, containing approximately 1.800 kcal, and maintained an average body mass of 36.7  1.0 kg (n = 34). A commercially prepared horsemeat-based mixture comprised [he dietary staple in 10 of 13 zoos responding to the survey, with additional whole or carcass portions offered 1-2 days per week to maintain variety and provide periodontal stimulation. Seven of 13 respondents fasted animals I day/week: five maintained no fast days. The primary meat product (n = 14 samples) contained: 58% crude protein. 28% crude far. 7% total ash, 52 Iu/kg vitamin E, 9.7 Iu/g vitamin A, and 2.200 mg/kg taurine (dry basis). Mineral content of the same food item was: 1.9% Ca. 10.0 mg/kg Cu, 645.2 m& Fe, 0.089 Mg. 22.6 rns/kg Mn, 1.3% P, 0.4% Na, and 127.8 mg/kg Zn. Nutrient levels, except vitamin E (and possibly Mg), met or exceeded recommendations established for domestic felids. Plasma a-tocopherol, retinol, and taurine (18.1, 1.82, 128.4 mol/L, respectively) concentrations were similar to normals for domestic felids, as were mean plasma mineral levels (n = 81: in mEq/L: 5.64 (Ca). 0.03 (Cu), 0.03 (Fe), 2.0 (Mg), 166.0 (Na). 12.3 (P), and 0.026 (Zn)). No gross physiological or dietary nutrient imbalances were evident from this survey.

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# Nutrition of Captive Cheetahs: Food Composition and Blood Parameters

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Diet and nutrition of cheetahs was evaluated through survey, in conjunction with chemical analysis of feed and plasma samples, as part of a multidisciplinary effort to investigate underlying causes of low reproductive success in North American captive cheetah populations. Cheetahs consumed an average of 1.32 ± 0.4 kg of food daily, containing approximately 1,800 kcal, and maintained an average body mass of 36.7 ± 1.0 kg (n = 34). A commercially prepared horsemeat-based mixture comprised the dietary staple in 10 of 13 zoos responding to the survey, with additional whole or carcass portions offered 1–2 days per week to maintain variety and provide periodontal stimulation. Seven of 13 respondents fasted animals 1 day/week; five maintained no fast days. The primary meat product (n = 14 samples) contained: 58% crude protein, 28% crude fat, 7% total ash, 52 Iu/kg vitamin E, 9.7 Iu/g vitamin A, and 2,200 mg/kg taurine (dry basis). Mineral content of the same food item was: 1.9% Ca, 10.0 mg/kg Cu, 645.2 mg/kg Fe, 0.08% Mg, 22.6 mg/kg Mn, 1.3% P, 0.4% Na, and 127.8 mg/kg Zn. Nutrient levels, except vitamin E (and possibly Mg), met or exceeded recommendations established for domestic felids. Plasma α-tocopherol, retinol, and taurine (18.1, 1.82, 128.4 μmol/L, respectively) concentrations were similar to normals for domestic felids, as were mean plasma mineral levels (n = 81; in mEq/L: 5.64 (Ca), 0.03 (Cu), 0.03 (Fe), 2.0 (Mg), 166.0 (Na), 12.3 (P), and 0.026 (Zn)). No gross physiological or dietary nutrient imbalances were evident from this survey. 

**Key words: cheetah, nutrition, feline**

## INTRODUCTION

Cheetahs (*Acinonyx jubatus*) reproduce poorly in captivity, and populations are rapidly diminishing. Although lack of genetic variation in this species has been demonstrated in both wild and captive populations [O'Brien et al., 1985], other researchers [Setchell et al., 1987; Gosselin et al., 1989] have suggested that dietary factors may be responsible for the impaired reproduction seen in captive animals. In

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particular, excess vitamin A and plant estrogens have been suggested as probable causes of liver disease and infertility, respectively.

Correlations between diet and reproductive success among institutions belonging to the American Association of Zoological Parks and Aquariums Species Survival Plan (SSP) for cheetahs have not been clearly significant [Marker and O'Brien, 1987]; however, preliminary data do suggest possible nutritional influences which need to be quantified. This investigation was conducted to compile baseline information on feeding practices, nutrient composition of primary diet ingredients, and physiological data useful for evaluating the nutritional status of cheetah populations.

## MATERIALS AND METHODS

### Survey of Diets

Through the Cheetah SSP, a survey was distributed to all member institutions requesting information on: 1) amount(s) and type(s) of meat products fed, including abrasives and treats in the diet, 2) feeding schedule, 3) dietary changes during reproduction/lactation, and 4) body mass/condition evaluation for individual cheetahs [for a copy of the survey, see Cheetah Research Council manual, 1989]. Results were previously summarized in the Cheetah Reproductive and Husbandry Survey and Guidelines distributed by the SSP in 1988, and will not be discussed in detail here. Rather, more specific diet and blood sample evaluations resulting from that initial survey are delineated.

### Chemical Analysis

Representative samples of meat products fed as the major diet constituent at various institutions were prepared by first homogenizing in a blender or meat grinder. Two subsamples (20 g, and 5 g mixed with 5 ml of a 50% sodium ascorbate solution) of each diet item were placed into labelled plastic bags, frozen at −20°C, and shipped overnight on dry ice to the Nutrition Laboratory, Animal Health Center, New York Zoological Society.

Per cent moisture, crude fat, protein, and ash values were obtained in duplicate according to AOAC methodology for meats [Ellis, 1984]. Total ash was determined on samples (0.5 g) incinerated at 550°C overnight. Fat content was determined following extraction with petroleum ether. Total nitrogen content was determined using a macro-Kjeldahl method with a copper catalyst. Mineral constituents were determined on freeze-dried samples by atomic absorption spectroscopy at the Animal Health Diagnostic Laboratory (East Lansing, MI). The taurine content of feed samples was quantified by reversed-phase HPLC as described by Sturman and Messing [1992]. Fat-soluble vitamins A and E were analyzed in subsamples mixed with sodium ascorbate, using the general methods of Taylor et al. [1976], with details of modifications and equipment as described by Pennino et al. [1991].

### Blood Analyses

Blood samples (15 ml in heparin) were collected from anesthetized cheetahs on an opportunistic basis. After centrifugation, plasma samples were stored at −20°C until overnight shipment to the Animal Health Center, New York Zoological Society. A total of 88 plasma samples were received from cheetahs held at 13 institutions in North America.



Fat-soluble vitamins were analyzed within 48 hr following arrival at the laboratory. Plasma tocopherols and retinol were measured by HPLC using a Series 400 system (Perkin–Elmer, Inc., Norwalk, CT) with a 30 cm C18 reversed-phase column. HPLC-grade methanol and water (98:2, vol/vol) was used as the mobile phase with a flow rate of 2.0 ml/min, following the general extraction methods of Storer [1974]. Tocopherols were monitored using a PE LS-1 fluorescence detector (excitation wavelength 280 nm, emission > 310 nm); retinol was detected at 325 nm on a Perkin–Elmer Model LC-95 on identically extracted samples, with solvent and integration systems as previously described. Inductively coupled argon plasma emission spectroscopy was used to determine plasma multielement profiles in 81 samples, as described by Braselton et al. [1981], using an Atomcomp Model 955 (Jarrell Ash-Vision, Fisher Scientific Co., Waltham, MA) at the Animal Health Diagnostic Laboratory (East Lansing, MI). Plasma taurine concentrations were determined in 47 samples, using methods previously described [Sturman and Messing, 1992] at the Institute for Basic Research (Staten Island, NY).

Statistical analyses were performed using the SYSTAT [Wilkinson, 1987] computer software package. Means were compared using one-way analysis of variance with a Tukey HSD value or a Student's *t*-test, with P levels set at 0.05 [Snedecor and Cochran, 1976]. Data in the text are presented as means, standard errors of means (SEM), and ranges.

## RESULTS

### Survey of Diets

Data from 13 institutions (including 10 of 26 respondees from the original survey) are included in this study. Commercially prepared frozen canine or feline diets comprised the dietary staple in these facilities, with a single product (Nebraska Brand Canine Diet, Central Nebraska Packing, Inc., North Platte, NE) the predominant feed in 10 zoos. Surveyed cheetahs consumed an average of 1.32 ± 0.4 kg (n = 34) commercial diet/day, a value identical to that estimated for free-ranging cheetahs in the Serengeti (1.3 kg food per day, range 0.3–3.4 kg) [Caro et al., 1987]. Additional whole carcasses or portions, including rabbit (0.5 kg), venison, chickens (1.4–1.7 kg), and horse or ox ribs/shank/tail were fed 1–2 times weekly in all institutions. Of these minor diet components, only chicken samples were submitted for chemical analysis.

Seven of 13 facilities maintained 1 fast day/week, while 5 others fed cheetahs daily, and one fasted 2 days/week. Cheetahs were generally fed once per day or, in the case of lactating or ill animals, offered the same quantity of food in 2 or 3 meals. No consistent diet alterations were detailed during pregnancy, lactation, or for geriatric animals.

Individual cheetah body mass (n = 34) averaged 36.74 ± 1.04 kg, with no significant gender difference between adults.

### Nutrient Composition of Diets

A total of 19 diet samples were analyzed, comprising canine diet (n = 14), feline diet (n = 3), and chicken (n = 2). Proximate composition, taurine, vitamin, and mineral content of these items is found in Table 1.

TABLE 1. Nutrient concentrations in primary meat items fed to cheetahs (*Acinonyx jubatus*) in North American zoos (mean ± SEM; all nutrients except water on a dry basis)

| Nutrient | Canine diet[a] (n = 14) | Feline diet[a] (n = 3) | Chicken (n = 2) | Feline Reqts.[b] |
|---|---|---|---|---|
| Water, % | 67.6 ± 0.5 | 58.4 ± 2.0 | 78.0 ± 6.2 | |
| Protein, % | 58.0 ± 1.5 | 55.7 ± 2.2 | 66.9 ± 7.5 | 28.0 |
| Taurine, mg/kg | 2,199.5 ± 186.0 | 1,629.8 ± 195.9 | 701.4 ± 449.1 | 400–500 |
| Crude Fat, % | 27.7 ± 1.1 | 41.0 ± 8.2 | 30.8 ± 1.9 | 9.0 |
| Vitamin E, Iu/kg | 52.4 ± 4.8 | 54.1 ± 13.1 | 9.5 ± 1.5 | 80.0 |
| Vitamin A, Iu/g | 9.7 ± 2.0 | 17.3 ± 5.0 | 11.7 ± 0.7 | 10.0 |
| Total Ash, % | 7.4 ± 0.4 | 8.9 ± 1.1 | 4.7 ± 1.0 | |
| Minerals, % | | | | |
| Calcium | 1.9 ± 0.2 | 1.3 ± 0.5 | 1.0 ± 0.4 | 1.0 |
| Magnesium | 0.08 ± 0.004 | 0.08 ± 0.01 | 0.06 ± 0.01 | 0.1 |
| Phosphorus | 1.3 ± 0.7 | 1.2 ± 0.8 | 0.8 ± 0.3 | 0.8 |
| Sodium | 0.4 ± 0.1 | 0.4 ± 0.1 | 0.3 ± 0.1 | 0.2 |
| Concentration, mg/kg | | | | |
| Copper | 10.0 ± 0.6 | 7.0 ± 0.5 | 6.0 ± 0.3 | 5.0 |
| Iron | 645.2 ± 94.2 | 632.7 ± 123.2 | 275.0 ± 174.5 | 100.0 |
| Manganese | 22.6 ± 9.4 | 27.3 ± 10.2 | 1.7 ± 0.9 | 10.0 |
| Zinc | 127.8 ± 9.5 | 132.3 ± 12.3 | 285.5 ± 125.2 | 30.0 |

[a]Nebraska Brand, Nebraska Packing, Inc., North Platte, NE.
[b]National Research Council, Washington, DC [1986].

## Plasma Constituents

Mean plasma α-tocopherol, retinol, taurine, and mineral concentrations from sampled cheetahs are presented in Table 2. Variations due to gender, institution, and/or primary diet (when available) were examined for each of these parameters; correlations between diet and plasma concentrations were not significant for any of the mineral, vitamin, or taurine levels compared.

## DISCUSSION

Based on intake information from the survey (1.3 kg food daily), and calculations from diet composition in Table 1 (assume 9 kcal per g fat, 4 kcal per g protein [dry matter basis], and diet digestibility of 90%), adult non-reproducing cheetahs consumed about 1,800 kcal daily. This value is somewhat lower than the 2,000–3,000 kcal required by a 37 kg cheetah estimated from generic mammalian energetics equations (140 kcal $(kg)^{0.75}$), or from data for domestic cats (about 80 kcal/kg body mass) [MacDonald et al., 1984]. Caro et al. [1987] reported that intake for free-ranging cheetahs (with presumably *greater* energetic needs) was, in fact, lower (75%) than that measured in cheetahs at the London Zoo. No qualitative data on diet composition were included in their study; nonetheless, it appears that approximately 50 kcal/kg body mass may be a practical estimate of calorie requirements for the captive cheetah. Neither emaciation nor obesity were reported as problems for the cheetah population surveyed in this report.



TABLE 2. Plasma α-tocopherol, retinol, taurine, and mineral concentrations in captive cheetahs (*Acinonyx jubatus*) in North American zoos*

| Component | n | x ± SE | Range | Felid normals[a] |
|---|---|---|---|---|
| Concentration, μmol/L | | | | |
| α-tocopherol | 88 | 18.14 ± 0.53 | 4.87–30.46 | 13.9–18.6 |
| Retinol | 88 | 1.82 ± 0.11 | 0.25–4.20 | 0.7–2.1 |
| Taurine | 47 | 128.4 ± 10.3 | 67.7–503.9 | >80 |
| Minerals, mEq/L | | | | |
| Calcium | 81 | 5.64 ± 0.08 | 4.65–9.55 | 4.11 |
| Copper | 81 | 0.03 ± .001 | .009–0.12 | |
| Iron | 81 | 0.03 ± 0.01 | 0.003–0.076 | 0.03 |
| Magnesium | 81 | 2.00 ± 0.03 | 1.50–3.17 | 1.83 |
| Sodium | 81 | 165.99 ± 2.33 | 143–291 | 147–156 |
| Phosphorus | 81 | 12.28 ± 0.24 | 8.94–18.1 | 3.76[b] |
| Zinc | 81 | .026 ± .001 | .015–.039 | 0.027 |

*The results can be converted into more conventional units by using the following factors: α-tocopherol, divide by 2.32 (μmol/L into μg/ml); retinol, divide by 3.5 (μmol/L into μg/ml); Ca 2.0 (mEq/L into mg/dl); Cu 3.2 (mEq/L into mg/dl); Fe 3.4 (mEq/L into mg/dl); Mg 1.2 (mEq/L into mg/dl); Na 2.3 (mEq/L into mg/dl); and Zn 3.3 (mEq/L into mg/dl).
[a]Summarized from Baker et al., 1986; Sturman, 1983; Coles, 1986; Kaneko and Cornelius, 1971; Jain, 1986; Kane et al., 1981.
[b]Feline normal level refers to inorganic phosphorus only; cheetah samples had total phosphorus (organic plus inorganic) quantified.

Nutritional requirements of domestic cats should form the basis of comparison in managed feeding programs for captive cheetahs. Both commercially formulated diets met or exceeded recommended feline requirements for all nutrients measured, except vitamin E and magnesium. Both canine and feline diets contained 4–6× higher levels of iron and zinc, compared with established requirements.

Although dietary vitamin E concentrations were less than recommended levels, mean plasma values indicated no sign of nutrient deficiency. In fact, plasma values for both α-tocopherol and retinol in cheetahs, as measures of vitamin E and A status, respectively, were within normal ranges previously reported for both domestic [Baker et al., 1986] as well as exotic [Schweigert et al., 1991] felids. Comparative concentrations measured in plasma samples collected from 4 free-ranging cheetah cubs in Namibia were 12.64 ± 2.78 and 1.75 ± 0.35 μmol/L (α-tocopherol and retinol, respectively). Cheetah plasma samples in this survey did not contain vitamin A esters as reported prevalent in many other zoo carnivores [Schweigert et al., 1990].

Previous studies [Gosselin et al., 1988, 1989] have documented evidence of vitamin A toxicity in cheetahs, associated with excess dietary levels of this nutrient. These data suggest that current commercial diets may contain more appropriate vitamin A levels than did earlier formulations of the same products. A cheetah liver sample (n = 1) obtained during this study contained retinol and α-tocopherol concentrations of 2,280 and 219 μg/g (wet), respectively. Values contrast with feline normals of 600–1,200 μg/g (retinol), and 20–40 μg/g (α-tocopherol), but are still considerably lower than liver retinol concentrations quantified in cheetahs with veno-occlusive disease (5- to 19-fold higher) [Gosselin et al., 1988].

Taurine deficiency associated with decreased fertility, retinopathy, and cardio-

myopathy in domestic cats has been well documented [Sturman, 1983; Pion et al., 1987]; similar syndromes have been described in exotic felids [Howard et al., 1987]. Felid dietary requirements for taurine vary from approximately 250 mg/kg in dry feed to >600 mg/kg in canned feeds, due to effects of heat processing on nutrient availability [Hickman et al., 1992]. Both commercial products contained adequate taurine, while the whole chickens analyzed in this study (see Table 1) may have been marginal. Although chickens were not fed as the sole diet to cheetahs in this survey and analyses need to be repeated with more samples, these data suggest that whole chickens may not be a suitable dietary staple for cheetahs or other felids due to a variable taurine content.

Five of 47 (11%) of the cheetahs in this survey had plasma taurine concentrations (Table 2) lower than felid normal values [Sturman, 1983], with no obvious relationship to sex, diet, or institution. Czekala and Lasley [unpublished report, 1988] found higher plasma taurine concentrations in recently captive South African cheetah cubs (289 ± 30 μmol/L; n = 30), consuming whole carcasses compared with the cheetahs described here. While the comparison may indeed be relevant, no evidence of general taurine insufficiency in the captive cheetah population was found through this survey.

Felid dietary recommendations for both macro- and micro-minerals were met or greatly exceeded by all three diet items evaluated in this study (Table 1), with the exceptions of magnesium (Mg) in general, and manganese specifically in the chicken samples [NRC, 1986]. Of particular concern for felids, high Mg levels may predispose cats to feline urinary syndrome through the formation of Mg ammonium phosphate salts (struvite) [MacDonald et al., 1984]. This condition has not been widely reported in zoo cheetahs [Weber et al., 1984]; the marginal Mg levels quantified may, in fact, be beneficial in minimizing disease incidence.

Excessive iron intake may be indicated by this diet evaluation. Hemosiderosis (deposition of iron in tissues) of unknown cause is common in many zoo species, and has been reported in zoo felids including cheetahs [Munson and Worley, 1991].

Health problems associated with excess dietary minerals have not been widely documented for the cheetah, and most plasma mineral concentrations (Table 2) were considered comparable to domestic felids, although direct comparisons using identical analytical methods were not available. Plasma calcium and sodium values for the captive cheetahs surveyed were slightly higher than domestic felid normals and concentrations measured in 17 free-ranging cheetahs (Ca = 4.6 mEq/L; Na = 162 mEq/L) [Caro et al., 1987], suggesting possible dietary mineral imbalances.

Copper (Cu) deficiency in cheetahs has been proposed in at least one published report [Brand, 1980] and 4 unpublished clinical case studies [Chance and Wilkinson, 1977; Downes and Hulett, no date; Cullinane, 1985; Zwart et al., no date]. Unfortunately, in none of these instances were dietary or plasma Cu concentrations quantified, nor could normal plasma values of this nutrient be found for felids. The mean value for cheetahs in this survey fell within normal plasma Cu levels (0.006–0.025 mEq/L) for other domestic and livestock species [National Research Council, 1980]. While both commercial diets and whole prey evaluated in this study contained more than the recommended dietary Cu requirement for felids, it is possible that dietary mineral interactions and/or imbalances (particularly iron and zinc) may affect copper metabolism. This question deserves further research attention in felids in general, and the cheetah in particular.



## CONCLUSIONS

1. Adult cheetahs (n = 34) from 13 North American zoological facilities consumed an average of 1.32 ± 0.4 kg food per day, containing approximately 1,800 kcal (calculated value), and maintained a healthy body condition at 36.7 ± 1.0 kg.

2. Protein, fat, vitamins E and A, taurine, and mineral concentrations in 2 commercially prepared diet mixtures, fed as staple diets to captive cheetahs, generally met or exceeded dietary nutrient recommendations established for domestic felids.

3. Plasma α-tocopherol (n = 88), retinol (n = 88), taurine (n = 47), and selected mineral (n = 81) concentrations from cheetahs at 13 North American institutions were within ranges considered normal for domestic felids; Ca and Na levels may have been elevated, and normal plasma Cu concentration is unknown.

4. No gross physiological or dietary nutrient imbalances, which may be adversely affecting reproduction in captive cheetahs, were evident from this survey, although data suggested that further research on mineral interactions (particularly Cu, Fe, and Zn) in cheetahs may be warranted.

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# ANNOUNCEMENTS

## CONFERENCE ON ENVIRONMENTAL ENRICHMENT FOR ZOO AND AQUARIUM ANIMALS

The Metro Washington Park Zoo in Portland, Oregon, will host the first conference specifically focused on the subject of environmental enrichment for zoo and aquarium animals. The Conference is planned for July 16–20, 1993.

Organized by Drs. David Shepherdson and Jill Mellen, the first two days of the conference will take the form of formal sessions: theoretical papers focused on specific topics, followed by quality case studies representing different taxonomic groups. The subsequent two days will include workshops held at the zoo, allowing for free exchange of ideas and information. The workshops will generate recommendations regarding the use of environmental enrichment in the management of captive animals.

The registration fee is $200, and space is limited. If you are interested in registering for the conference, write to the address below:

First Conference on Environmental Enrichment
Metro Washington Park Zoo
4001 SW Canyon Rd
Portland, OR 97221
Phone: (503) 220-2446
Fax: (503) 226-0074

## LION-TAILED MACAQUE SYMPOSIUM

The 4th International Lion-Tailed Macaque Symposium will be held in Madras, India, from October 11 to 15, 1993. The host of the Symposium will be: The Forest Department of Tamil Nadu, the Zoo Outreach Organization, and CBSG-India and its Lion-Tailed Macaque Special Interest Group. A major part of the Symposium will be a Population and Habitat Viability Assessment (PHVA) of the wild lion-tailed macaque, *Macaca silenus*, population.

A PHVA is an intensive analysis of the conservation status of a species, subspecies or population using computer models to: (1) explore extinction processes that operate on small and often fragmented populations of threatened taxa, and (2) examine the probable consequences for the viability of the population of various management actions or inactions. Another part of the Symposium will be a workshop to develop a global program and master plan for the management and propagation of the captive population, to maximize its contribution to the conservation of the species. The Captive Breeding Specialist Group (CBSG) of the IUCN Species Survival Commission will provide technical support for these workshops.