
Keywords: Acinonyx jubatus/analysis/body mass/captive breeding/captivity/cheetah/diet/feeding/husbandry/nutrition/reproductive success/research/survey/zoo

Abstract: 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 Fe, 0.089 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 a-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.
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 fecal analysis of feed and plasma samples, as part of multidisciplinary effort to investigate underlying causes of low reproductive success in North American captive cheetah populations. Cheetahs consumed an average of 1.2–2.4 kg of meat 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 food mixture comprised the daily staple in 10 of 13 zoos responding to the survey, and variety and provision of periodic stimulation. Seven of 13 respondents fasted animals 1 day/week, five maintained no fast days. The primary meat product (n = 34 samples) contained: 58% crude protein, 28% crude fat, 7% total ash, 52 g/kg vitamin E, 9.7 mg/kg vitamin A, and 2.200 mg/kg thiamine (dry basis). Mineral content of the same food item was: 1.9% Ca, 10.0 mg/kg Cu, 645.2 mg/kg Fe, 0.089 mg/kg Mn, 1.39 mg/kg Na, and 127.8 mg/kg Zn. Nutrient levels, except vitamin E (and possibly Mg), were not or exceeded recommended standards for domestic felines. Plasma α-tocopherol, retinol, and taurine (18.1, 129.4 μmol/L, respectively) concentrations were similar to normals for domestic felines, as were mean plasma mineral levels (n = 81; in mM/L: 5.64 Ca, 0.03 Cr, 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 in this survey.

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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]; but 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 released 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 580°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 (13 ml in heparin) were collected from anaesthetized 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.

RESULTS
Survey of Diets

Data from 13 institutions (including 10 of 26 respondents 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 simple product (Nebraska Brand Canine Diet, Central Nebraska Packing, Inc., North Platte, NE) the predominant feed in 12 of 15 surveys. 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 0.25–3.4 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 giblets/epiglottis 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, 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)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Canine diet*</th>
<th>Feline diet*</th>
<th>Chicken (n = 2)</th>
<th>Feline Rog*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water, %</td>
<td>67.6 ± 6.5</td>
<td>58.4 ± 2.0</td>
<td>75.0 ± 6.2</td>
<td>28.0</td>
</tr>
<tr>
<td>Protein, %</td>
<td>58.0 ± 1.5</td>
<td>55.7 ± 2.2</td>
<td>66.1 ± 7.5</td>
<td>28.0</td>
</tr>
<tr>
<td>Threonine, mg/kg</td>
<td>2,190.5 ± 189.6</td>
<td>1,629.8 ± 159.9</td>
<td>700.4 ± 449.1</td>
<td>400-500</td>
</tr>
<tr>
<td>Crude Fat, %</td>
<td>27.7 ± 11.1</td>
<td>41.0 ± 8.2</td>
<td>30.8 ± 18.9</td>
<td>9.0</td>
</tr>
<tr>
<td>Vitamin E, mg/kg</td>
<td>52.4 ± 4.8</td>
<td>54.1 ± 12.1</td>
<td>9.5 ± 1.5</td>
<td>80.0</td>
</tr>
<tr>
<td>Vitamin A, IU</td>
<td>9.7 ± 2.0</td>
<td>17.3 ± 5.0</td>
<td>11.7 ± 0.7</td>
<td>10.0</td>
</tr>
<tr>
<td>Total Ash, %</td>
<td>7.4 ± 0.4</td>
<td>8.9 ± 1.1</td>
<td>4.7 ± 1.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Minerals, %</td>
<td>2.0 ± 0.2</td>
<td>1.3 ± 0.5</td>
<td>1.0 ± 0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.08 ± 0.004</td>
<td>0.08 ± 0.01</td>
<td>0.06 ± 0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Magnesium</td>
<td>3.3 ± 0.7</td>
<td>3.8 ± 0.8</td>
<td>0.8 ± 0.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.4 ± 0.1</td>
<td>0.4 ± 0.1</td>
<td>0.3 ± 0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Nebraska Brand, Nebraska Packing Inc., North Platte, NE.

Plasma Constituents

Mean plasma 2,2’-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 1.8 kcal daily. This value is somewhat lower than the 2.0-3.0 kcal required by a 37 kg cheetah estimated from general mammalian energetics equations (140 kcal/kg75), 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 energy requirements for the captive cheetah. Neither emaciation nor obesity were reported as problems for the cheetah population surveyed in this report.

NUTRITIONAL REQUIREMENTS OF DOMESTIC CATS SHOULD FORM THE BASIS OF COMPARISON IN MANAGED FEEDING PROGRAMS FOR CAGE CHEETAHS. BOTH COMMERCIALLY FORMULATED DIETS AND OR EXTRAS RECOMMENDED FELINE REQUIREMENTS FOR ALL NUTRIENTS, EXCEPT VITAMIN E AND MAGNESIUM. BOTH CANINE AND FELINE CATS CONTAINED 4-6X 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 2,2’-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 cheetahs in Namibia were 12.64 ± 2.78 and 1.75 ± 0.35 µmol/L (2,2’-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 2,2’-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 (2,2’-tocopherol), but are still considerably lower than liver retinol concentrations quantified in cheetahs with vaso-occlusive disease (5-10 fold higher) [Gosselin et al., 1988].

Taurine deficiency associated with decreased fertility, retinopathy, and cardio-
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, and selected minerals (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.

3. 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.

ACKNOWLEDGMENTS

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