Nutrition of the Exotic Felid

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OBESITY in both domestic and captive exotic cats is increasing. Captive exotic felids lack exercise due to limited exhibit space and are no longer required to expend energy to obtain food. Obesity may have negative consequences on health, appearance, longevity and reproductive efficiency of captive exotic animals. Although exotic felids vary in body size and diet in the wild, they often are fed similar diets in captivity, including commercially-prepared raw meat diets.

Raw meat poses a risk to keepers handling it as well as does the feces of the cats ingesting the raw meat. Feeding an extruded kibble diet may be a viable option for small exotic cats that likely have similar nutrient requirements and energy needs as domestic cats. Crissey et al. (1997) measured nutrient digestibility and blood metabolites of sand cats (*Felis margarita*) fed an extruded kibble diet compared with a raw meat diet. While nutrient digestibilities decreased (dry matter [DM], 12.9% change; crude protein [CP], 15.7% change) when cats consumed the extruded kibble diet, the authors suggested that this diet may be utilized as a food source by sand cats. To date, that study has been the only one focused on the ability of small exotic felids to utilize extruded kibble diets.

Captive large exotic felids often are fed commercially-prepared raw meat diets or skeletal muscle with supplemental vitamins and minerals. Apparent total tract nutrient digestibilities have been reported in a wide range of felid species, but often represent only a small number of animals per species due to the small number of these animals located in each zoological park (Morris et al., 1974; Barbiers et al., 1982; Wynne 1989; Dierenfeld, 1993; Altman et al., 2005). While feeding recommendations for large exotic felids are based on known nutrient requirements of domestic cats, published research has not directly compared species fed the same diets.

Furthermore, conducting nutritional research in zoos is difficult due to limitations including small population sizes, animal handling difficulties and diet types. Moreover, the design of animal enclosures, the challenge of feeding animals individually while respecting formed social groups and the time required by zoo staff to perform a digestibility trial often make them very difficult or impossible to conduct.

There is great diversity among exotic felids, and it is apparent that more research is needed to understand how they differ from domestic cats. Exotic felids feed on prey available in their native habitat, and the type of prey is dependent on the size of the felid. Ecological data defining the prey these animals are consuming, and the parts of the prey being consumed will guide future nutrition research on captive felid populations.

Diversity of exotic felids

Great diversity exists as regards the anatomical and behavioral aspects of exotic felids in existence today. This family of animals range in size from African wildcats, which are the size of domestic cats (3-7 kg), to tigers that can weigh as much as 280 kg. To add to the complexity, nutritional needs of exotic felids are poorly defined. Although ecological studies have been conducted on many of the species regarding prey consumption and feeding patterns, no studies reporting nutrient profiles of prey animals in the wild exist. Therefore, nutritionists extrapolate diet formulations for exotic felids based on dietary requirements of domestic cats. One importaNt feeding behavior that may relate to nutrient requirements of large felids is the initial consumption of the viscera. This behavior may provide fat and vitamin needs (Lindburg, 1988), as well as dietary fiber contained within the visceral contents. Skeletal muscle, bone and cartilage then are consumed, providing protein and a source of "animal fiber" (mainly connective tissue containing chondroitin sulfate and hyaluronic acid).

Ecological data including geographical habitat locations have provided clues to nutrient requirements and ability to utilize different types of foods for many of the exotic felid species. Available prey in a specific geographical location largely determines what felids will hunt, but size of the cat and opportunity to catch prey are other factors. For example, bobcats are common throughout North America and have a generalist diet in the wild that includes several species of small mammals and birds and occasionally deer, especially in winter (Nowak, 1999). Cheetahs, meanwhile, primarily roam in eastern and southern Africa and consume gazelle and small antelope (Nowak, 1999).

Apparent total tract digestibility

Extensive testing of the digestive capability of exotic felids is lacking. Barbiers et al. (1982) evaluated the digestibility of a commercially-prepared raw horsemeat-based diet (17.7% CP; 15.6% fat) by captive exotic felids. One male and one female of the following species were utilized in that study: cougar (*Felis concolor*), leopard (*Panthera pardus*), African lion (*Panthera leo*) and tiger (*Panthera tigris*). Chromium sesquioxide was added to the diet at approximately 0.3% of wet weight to determine total tract apparent nutrient digestibility. Total feces were collected for 3 days following 2 consecutive days of consuming the marked diets. Barbiers et al. (1982) reported 83.1-89.7% CP digestibility values and 94.5-99.0% ether extract digestibility values. CP values were higher than those presented by Wynne (1989), who noted an average of 79.2% digestibility. Fat digestibility also was higher than those of Wynne (1989) who reported 91.5% digestibility (average for all species). Barbiers et al. (1982) noted that all animals were fed one large meal per day, but did not specify if food refusals were analyzed for chromium to determine accurate food consumption data. These factors, in addition to low animal numbers, likely added to intra- and inter-species variation.

Another study (Wynne, 1989) evaluated the digestibility of a commercially prepared raw beef and horse meat loaf diet (43.4% CP; 28.5% fat) by African lions (*P. leo*, n = 4), tigers (*P. tigris*, n = 4), puma (*Felis concolor*, n = 4) and leopards (*P. pardus*, n = 4). Animals were fed the diet for a minimum of two months prior to the collection period. Animals were fasted on day 1, subsequently fed 2-4% of bodyweight on days 2-7, and total feces were collected on days 2-7.

Wynne (1989) noted average CP and fat digestibilities of approximately 79.2% and 91.5%, respectively, for all species, but did not observe differences among species or sex. In general, all species utilized the diet well. Protein digestibility, however, was inversely related to body size, suggesting that the diet may not be best suited for the smaller species studied (pumas and leopards). Wide variation within species suggested that larger populations should be studied. Because the number of each species is often small in each zoological park and the populations may become transient across zoos to maintain genetic diversity when mating, such studies are difficult to conduct.

The dangers of handling a raw meat diet (i.e., bacterial contamination) have convinced some zoo nutritionists to feed small exotic felids a dry, extruded diet as a full or partial substitute for raw meat. Irradiation of raw meat does not affect diet consumption or fecal consistency, but may prove too expensive and/or time consuming for zoos (Crissey et al., 2001). Crissey et al. (1997) measured the ability of sand cats (n = 8; *F. margarita*) to digest a raw meat versus a kibble diet. Following a 7-day adaptation phase, total tract DM, CP and energy digestibilities were determined on days 8-12 of each period. Apparent total tract DM (83.5 ± 4.8% raw; 72.7 ± 12.3% dry), energy (89.6 ± 5.2% raw; 76.8 ± 14.5% dry) and CP digestibilities (92.4 ± 5.3% raw; 77.9 ± 13.5% dry) were lower numerically when cats consumed the dry, extruded diet. Blood metabolites, including taurine and retinol concentrations, were within normal ranges for cats; however, values were highly variable among cats (Crissey et al., 1997). The authors concluded that although digestibility appeared to decrease when cats were fed the dry, extruded diet, it served as a suitable replacement for small cats. This study had several limitations. First, all cats consumed the raw meat diet during the first period followed by the dry, extruded diet during the second period, thereby not allowing statistical analysis. Second, individually-housed cats were fed two times daily during the first period and *ad libitum* after 7 days of the second period. Between periods, cats were adapted to the dry diet over the course of 6 months.

In a zoological and home setting, diet may affect nutritional status and feeding behavior. Large felids in the wild often gorge after making a kill, but then may not consume another meal for several days. This behavior is unlike that of the domestic cat who eats several small meals throughout the day. To evaluate changes in nutrient digestibility and behavior of captive lions (*P. leo*), a modified feeding schedule was tested (Altman et al., 2005). Lions (n = 5; mean bodyweight = 157.9 kg) were slowly transitioned from a 6 days fed / 1 day fast feeding schedule (week 0) to a 3 days fed/ 4 days fast schedule (weeks 7 and 8). The end of the study (weeks 9 and 10) constituted the gorge and fast period where lions were on a 3 days fed/ 4 days fast schedule, where the fast days were selected at random, and could consist of any number of consecutive fasting days. The last two weeks were compared with week 0 for all analyses conducted.

Over the course of that study, apparent DM, fat and CP digestibilities numerically increased from the 6 days fed/ 1 day fast period to the 3 days fed/ 4 days fast period. During that time, lions had an average bodyweight decrease of 7%, although body condition score of these animals was not reported. Although the authors noted that the decreased bodyweight was a benefit of the study because animals were a healthier weight (lighter) during the 3 days fed/ 4 days fast period, the change in bodyweight confounds the digestibility data (Altman et al., 2005). Behavior was not changed, with most of the time spent resting. However, there was a decrease in pacing during days of fasting. Stereotypic behaviors, such as pacing, are a common problem in zoos and any decrease in these behaviors are beneficial to the animal. Using nutrition or feeding strategy as a tool for enrichment may improve animal well-being and behavior.

Apparent total tract nutrient digestibility (Table) and fermentative end-products were determined (Vester et al., 2008) using five species of captive exotic felids, including bobcats (*Lynx rufus*; n = 2), jaguars (*Panthera onca*; n = 4), cheetahs (*Acinonyx jubatus*; n = 5), Malayan tigers (*P. tigris corbetti*; n = 4), and Amur tigers (*P. tigris altaica*; n = 5). Due to limited space for disposal of fecal output by large animal numbers and public proximity to the caging in zoos, decreasing fecal putrefactive compounds is of importance. All animals were fed a raw beef-based diet commercially prepared and intended for non-domestic felid species (Nebraska Brand Special Beef Feline).

It was noted that fat digestibility was greater in Amur tigers, Malayan tigers and bobcats (96%) compared with cheetahs and jaguars (94%; Vester et al., 2008). Energy digestibility was greater in bobcats and Malayan tigers at 93.5 and 92.9%, respectively, compared with cheetahs and jaguars (91.6%). Fecal pH was greater in bobcats compared with all other species evaluated. Fecal indole concentrations were

Apparent total tract nutrient digestibility by large exotic felids fed a beef-based raw diet (Vester et al., 2008)

	Species				
	Bobcat	Jaguar	Cheetah	Malayan tiger	Amur tiger
Number	2	4	5	4	5
Bodyweight, kg	13.3	58.0	41.2	105.3	122.6
Apparent total tract digestibility, %					
DM	89.5	87.9	87.3	88.9	87.8
Organic matter	89.3	87.7	87.0	88.7	87.5
CP	93.9	92.5	92.6	93.2	92.5
Fat	95.1[b]	93.9[a]	94.0[a]	96.1[b]	96.2[b]
Fiber	50.8	46.7	48.6	47.0	42.4
Energy	93.5[b]	91.6[a]	91.6[a]	92.9[b]	92.6[ab]

[a,b,c]Means within a row lacking a common superscript letter are different (P < 0.05).

greater in cheetahs and jaguars compared with bobcats and Malayan tigers. Fecal ammonia concentrations were greater in cheetahs compared with all other species. This was the first study to report fecal fermentative end-products in captive exotic felids.

We concluded that several small yet significant differences exist among exotic felid species. Interestingly, apparent total tract digestibility and fecal end-products of bobcats were closely associated to that of Malayan and Amur tigers, while jaguars and cheetahs had similar values in many of these measurements. This relationship may have been due the wild-type diet for each of these species. Bobcats are considered generalists and consume various types of prey, while tigers consume large mammalian prey, including gaur and buffalo, which may have a closer nutritional profile to the raw beef-based diet compared with prey commonly consumed by wild jaguars and cheetahs. Therefore, the wild-type diet of each species may be an important consideration when formulating a diet for these species.

Domestic cat as a model

To our knowledge, there is no published research directly comparing domestic cats to exotic felids fed the same diet(s). Because of their close evolutionary lineage, the domestic cat serves as a model for determining nutrient and energy requirements and feeding methods for captive felid populations. To set feeding guidelines, nutritionists often utilize blood metabolite concentrations and digestibility estimates of domestic cats.

Digestibility of raw meat diets varies widely among studies, and information on diet composition and quality often is limited (Barbiers et al., 1982; Wynne, 1989; Crissey et al., 1997). A survey of diets fed to cheetahs in North America reported that most zoos fed a commercially-prepared canine diet (Nebraska Brand), a commercially-prepared feline diet (Nebraska Brand) or a chicken-based diet (Dierenfeld, 1993). The use of commercially-available raw diets is common among zoos to provide a complete diet, although some prefer to feed skeletal muscle with supplemental vitamins and minerals.

Bechert et al. (2002) compared blood metabolites of captive cheetahs (n = 12) to those of domestic cats to determine if a raw meat diet adequately met their nutritional needs. A commercially-prepared raw meat diet (Nebraska Brand Canine Diet) or skeletal meat (beef, horse, venison or turkey drumstick) with vitamin supplementation was fed for one year. Blood metabolite concentrations indicated that the commercial diet provided excessive concentrations of vitamins A and E but met all other needs. Studies similar to Bechert et al. (2002) are limited due to the difficulty of collecting blood samples from exotic felids.

The diets utilized in digestibility trials with domestic felids often contain a greater fat and protein content than is required by the domestic cat. These diets appear to be highly variable, even among commercially manufactured diets. Daily metabolizable energy (ME) requirements of domestic cats is 100 kcal x kg $BW^{0.67}$ for lean domestic cats, while for exotic cats ME requirements are estimated to be between 55-260 kcal x kg $BW^{0.75}$ (NRC, 2006). Allan et al. (1995) reported that ME requirements could not be extrapolated from domestic cats due to the large variation within and among exotic felid species. Digestible energy intake, expressed relative to metabolic bodyweight (kcal/ kg $BW^{0.75}$), was 150-185 in cheetahs and 200-260 in Sumatran tigers (Allan et al., 1995). The authors suggested that, of the species evaluated in that study, young clouded leopards and lions were similar to domestic cats, but cheetahs and tigers required more energy to maintain bodyweight.

Although details regarding nutrient metabolism by exotic felids are still sparse, their close evolutionary relationship to domestic cats suggests that basic nutritional requirements may be determined using this model. Furthermore, exotic felids share many of the same nutrition-related maladies reported in domestic cats, including renal disease, hyperlipidemia, food allergies and obesity. The increasing rate of captive exotic felid obesity mirrors that of domestic cats, and is likely caused by similar mechanisms.

Conclusions

Although nutritionists have determined many feline metabolic peculiarities over the past few decades, many questions remain. These scientific advances have improved the health and nutritional status of not only domestic cats but also captive exotic felid species. When developing diets for felidae species, it is important to consider the type and chemical composition of diets consumed in the wild. Furthermore, evaluation of dietary composition will improve the nutrition and health of both domestic and wild felids.

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