Influence Of Fiber Source On Apparent Digestibility, Rate Of Passage And Fecal Consistency In Small Felids Fed A Beef-based Carnivore Diet

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In a crossover design, four adult animals, a male and female Amur leopard cat (*Prionailurus bengalensis euptilura*) and a male and female Turkmenistan caracal (*Caracal caracal michaelis*) were fed three fresh-frozen beef based diets containing different sources of fiber; beet pulp (BP), fructooligosaccharides/cellulose blend (FOS), and wood cellulose (Solka Floc®) (WC). Assessment included food intake, fecal consistency, animal body weight, apparent dry matter digestibility of each diet, and transit time. Diets were formulated to be isofibrous (12.5% total dietary fiber (TDF)). Fecal evaluation and collection were conducted daily. Physical characteristics of feces were scored using an established index of 1 (dry, crumbly) to 5 (high moisture, loose). Animal body weights were maintained throughout the study. Dry matter intake for the diets containing BP, FOS, or WC was 14.3, 16.3 and 15.2 g kg^{-1} BW, respectively. The apparent dry matter digestibility (%, ADMD) for the respective diets was 70.2, 74.1 and 67.0. The ADMD for the WC diet was lower ($P < 0.05$) than the FOS diet but similar to the BP containing diet; there were no observed differences in ADMD between the WC and FOS diets ($P > 0.05$). The average fecal index score (FIS) for the FOS diet was higher than BP and WC diets (2.90 vs 2.33 and 2.35); however the average FIS for the cats fed the respective diets were within the acceptable range of 2.0 to 3.0. Although transit time values empirically appeared to be slower for the FOS diet, this difference was only observed in one of the three animals. The fresh-frozen beef based diets consisted primarily of human-quality beef that was USDA approved and all diets were palatability, digestible, safe and nutritionally balanced.

Key words: *Caracal caracal michaelis; Prionailurus bengalensis euptilua*; beet pulp; fructooligosaccharides; cellulose

INTRODUCTION

North American zoos have historically experienced challenges with commercial carnivore diets, including, but not limited too, poor palatability, variable food consumption, inconsistent dietary nutrient densities, and contamination of the diets with foreign substances [Crissey et al., 1997; Allen et al., 1999]. Additionally, these concerns have been directly linked to health and management issues that have impacted the morbidity and mortality of captive carnivores, many of which are endangered species [Setchell et al., 1987].

The Zoological Society of San Diego (ZSSD), along with the Smithsonian's National Zoological Park, provided the leadership to improve the diets of captive carnivores by defining the types of diets required and not accepting "off the shelf" formulations [Allen et al., 1999]. Recognizing socio-economic changes that influence raw meat ingredient availability, most notably the decline of horsemeat production in North America, the ZSSD formulated specifications for a beef-based carnivore diet to meet the specific requirements of our diverse animal collection.

Practical field data collected over 18 months suggested that modifications to the initial formulation may be required to address specific species requirements and to incorporate recently published data regarding the benefits of specific fiber sources in carnivore diets [Kelley et al., 1998; Sparkes et al., 1998a, Sparkes et al., 1998b; Sunvold et al., 1995a, Sunvold et al., 1995b, Sunvold et al., 1995c; Sunvold and Reinhart, 2000].

The objectives of this initial study were to assess the influence of specific fiber sources, wood cellulose, beet pulp and fructooligosaccharides (FOS), on food intake, fecal consistency, animal body mass, dry matter digestibility of each diet and transit time.

MATERIALS AND METHODS

Collection period was from 16 December 2000 through 23 February 2001. This time period was chosen due to the absence of elevated environmental temperatures; anecdotal observations have suggested that food intake of carnivores may be suppressed with high environmental temperatures. The experimental protocol was coordinated within the established routines of daily animal care and enclosure maintenance and monitored by the institution's IACUC committee.

Animals and Housing

Four adult animals, a male and female Amur leopard cat (*Prionailurs bengalensis euptilura*) and a male and female Turkmenistan caracal (*Caracal caracal michaelis*) were included in this portion of the study. Based on records of previous physical examinations and current medical status, there were no apparent health problems with these animals.

All animals were housed individually in chain link enclosures with cement floors containing several resting platforms, a partially enclosed kennel and a separate area with a heated floor.

Diets and Collection Phase

Three beef based carnivore diets were formulated to fulfill AAFCO requirements for domestic cats. Diets were individually fed to the animals in a crossover design [AAFCO, 2000]. Each diet was formulated to be isofibrous (12.5% TDF) with the sources of fiber including beet pulp (BP), a 3:1 blend of wood cellulose and fructooligosaccharides (FOS) , or wood cellulose (Solka Floc®) (WC). Diets were labeled as A, B or C by the manufacturer (Natural Balance Pet Foods, Pacoima, CA). Formulas corresponding to the generic label were known by a collaborating author, but not by the individuals directly involved in the collection of the data or the fecal index score evaluation. The order in which each cat would receive the three diets was determined randomly at the beginning of the study. Selected nutrient composition of the three diets is provided in Table 1.

Each trial was divided into three phases following the digestibility protocol defined by AAFCO [2000]. This protocol included a five-day transition period from the previous diet, an eleven-day acclimation to the test diet, and a five-day collection period. This process was repeated for each dietary treatment until all animals had been fed the three diets.

Quantities of the test diets fed were based on the total calories delivered by the pre-trail standard diet that maintained body weight. Other food items (kibble and mice), traditionally provided as part of the species standard diets, were not offered during the study. Bones fed for enrichment and to improve oral health were not provided during the five-day collection period. Additionally, fast days were also eliminated by equally distributing weekly caloric intake over seven days that included the 5-day collection period.

Daily amounts of food offered were quantified to 1 g. During the five-day collection period, the diets were fed between 0700 and 0800 h. Fecal evaluation and collection were conducted daily immediately prior to presentation of the test diet. Physical characteristics of feces were scored using an established index of 1 to 5 (Table 2); 1 representing feces that are dry and crumbly; 5 representing feces that are high moisture and loose; fecal score indexes (FSI) that are acceptable range from 2 to 3 [Edwards, 1997]. Fecal samples were collected into a clear plastic ziploc-type bag, and weighed to 1 g. The collection bag was labeled with the animal ID, collection and drying dates, and the fecal weight. The fecal samples were subsequently frozen until required for further processing and analysis.

Digesta Markers

A single pulse bolus of 110 1mm acetate beads were fed to each cat during the AM meal on day one of collection in order to determine rate of passage and retention times. Following administration of the markers, fecal samples were collected every three hours until 1800 h. Daily collections resumed the following morning. Fecals were collected until 90% of the administered dose was recovered. Markers were again administered to each animal on day five of collection to identify the termination of this collection period and to include the last stool for analysis. Transit time (TT_1) was determined as the first appearance of the markers in the collected feces.

Analysis

Test diets were submitted to an independent laboratory for analysis of moisture, crude protein, ether extract, total dietary fiber, calcium, phosphorus and gross energy.

Frozen fecal samples were transferred to aluminum pans and dried at 50°C via forced air oven. Samples were dried to a constant weight and then ground to 1mm with a Thomas-Wiley mill fitted with a 1mm screen. Small amounts of cat hair that passed in the feces were removed and weighed. This "hair weight" was subtracted from the final oven dried weight to determine the actual fecal output.

Sequential dry matter and total ash of the partially dried fecal samples were completely according to the National Forage Testing Associations protocols [1993]. Apparent dry matter digestibility was then calculated using the following relationship between dry matter intake (DMI) and total fecal dry matter:

$$ADMD\% = [(DMI - Fecal\ DM)/DMI]*100$$

RESULTS

Beginning and post trial body weights (kg), species and gender of the cats in this study are identified in Table 3. The diets were formulated to be isofibrous (12.5% TDF), however actual laboratory analyses demonstrated that TDF of the WC treatment was actually higher; TDF for diets containing BP, FOS, and WC was 12.6, 12.3 and 17.1 %, respectively.

Dry matter intake (DMI) for the diets containing BP, FOS, or WC was 14.3, 16.3 and 15.2 g kg^{-1} BW, respectively (Table 4). Animal body weights were maintained throughout the three collection periods. The apparent dry matter digestibility (%, ADMD) for the respective diets averaged 70.2, 74.1 and 67.0 (Table 5). The ADMD for the WC diet was lower ($P < 0.05$) than the FOS diet but similar to the beet pulp containing diet; there were no observed differences in ADMD between the BP and FOS diets ($P > 0.05$).

The average fecal index score (FIS) for the FOS diet was higher than beet pulp and WC diets (2.90 vs 2.33 and 2.35); however the average FIS for the cats fed the respective diets were within the acceptable FIS range of 2.0 to 3.0 (Table 6). One of the cats refused the food bolus containing the marker, thus marker transit data was not collected for this individual. Although TT_1 empirically appeared to be slower for the FOS diet compared to the BP and WC diets, this difference was only observed in one of the three animals (Table 7).

DISCUSSION AND CONCLUSIONS

Regardless of the fiber source, the beef based diets containing 12.5% TDF adequately maintained the body weights of the cats. All diets were palatability, digestible, safe and nutritionally balanced. These fresh-frozen beef carnivore diets consisted primarily of USDA approved (human-quality) beef. All of the beef and beef products used in these formulas originated from meat plants governed by the USDA Food Safety and Inspection Service (FSIS). Providing diets that not only will meet the nutritional requirements of carnivores, but also can be prepared and handled to address sanitation and food safety is a fundamental objective of the ZSSD's dedication to the reproduction, protection and exhibition of animals. It was not unexpected that the FOS diet, consisting of fructooligosaccharides, had the highest ADMD, since this fiber source is considered to be highly fermentable. The diet containing WC, a pure form of cellulose, produced a significantly lower ADMD then the fructooligosaccharides containing diet (74.1 vs 67.0). The lower ADMD for the WC diet may have resulted from the higher %TDF; i.e., 17.1 vs 12.6 and 12.3% for the BP and FOS diets. However, fermentation in the hindgut of carnivores is generally considered as very limited. Nevertheless, nutritional understanding of other species would suggest that cellulose-containing diets would be less digestible than diets containing more fermentable fiber sources such as beet pulp, soybean hulls, psyllium, etc. Beet pulp contains high levels of hemicellulose and is also considered a fermentable fiber source for omnivores and herbivores; therefore, the lack of differences in the ADMD of the BP and FOS diets is not surprising. The cats fed the WC and BP containing diets consistently had similar and acceptable averaged FIS of 2.0 to 2.6. The fiber content of these diets would provide an opportunity for stools of a carnivore to be well formed. The average FSI of the FOS diet was higher (2.9) but also within the acceptable range of 2.0 to 3.0. Although from a practical perspective, these differences are not a management or health issue, the differences most likely can be contributed to the differences in fermentable fiber source.

The beef-based diets used in this project regardless of fiber source are safe. Following over two and a half years of practical use of these diets with a variety of carnivores, they have supported all stages of life, including growth,

gestation, lactation and maintenance. An important consideration in formulating fresh frozen carnivore diets is to use beef and beef products that originated from meat plants governed by the USDA Food Safety and Inspection Service (FSIS). The production and distribution of the specifications for a beef-based carnivore diet will not only improve the nutritional health of animals within our own collections, but also improved those managed by AZA Taxon Advisory Groups, AZA Institutions and related organizations that implement their use.

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TABLE 1. Selected nutrient composition of the three beef-based carnivore diets with varying fiber sources: beet pulp (BP), cellulose/ fructooligosaccharide 3:1 blend (FOS), and wood cellulose (WC)

Diet	Moisture, %	DMB					
		GE,kcal g^{-1}	CP, %	EE, %	TDF, %	Ca, %	P, %
BP	61.0	5.72	42.6	22.8	12.6	1.84	1.04
FOS	60.3	5.99	40.1	25.4	12.3	1.51	0.95
WC	60.3	5.82	38.0	21.4	17.1	1.76	1.03

TABLE 2. Fecal consistency scoring scale and descriptions of each score used to evaluate fecal consistency in small felids[1]

Score	Description
1	dry, crumbly
2	well formed
3	slightly moist, good, less formed
4	moist, badly formed
5	High moisture, loose, lacking form

[1]Adapted from Edwards and Zhang, 1997.

TABLE 3. Body weights (kg) of study subject immediately prior to (pre-trial), and immediately following each dietary treatment indicated by specific fiber source: beet pulp (BP), cellulose/fructooligosaccharide 3:1 blend (FOS), and wood cellulose (WC)

Species	Animal	PreTrial	Dietary treatment		
			BP	FOS	WC
Turkmenistan	female	6.70	5.80	5.90	5.95
caracal	male	10.60	10.00	10.05	9.45
Amur	female	4.72	5.15	4.75	4.95
leopard cat	male	5.88	5.95	5.80	5.90

TABLE 4. Dry matter intake g kg^{-1} BW of two small (< 15 kg) felid species fed three different beef-based carnivore diets with varying fiber sources: beet pulp (BP), cellulose/fructooligosaccharide 3:1 blend (FOS), and wood cellulose (WC)

Species	Animal	Dietary treatment		
		BP	FOS	WC
Turkmenistan caracal	female	16.4	16.5	16.3
	male	14.6	15.0	15.9
Amur leopard cat	female	10.7	17.8	12.8
	male	15.3	16.1	15.8
Mean		14.3	16.3	15.2

TABLE 5. Dry matter digestibility (%) of three different beef-based carnivore diets with varying fiber sources: beet pulp (BP), cellulose/fructooligosaccharide 3:1 blend (FOS), and wood cellulose (WC) fed to two small (< 15 kg) felid species

Species	Animal	Dietary treatment		
		BP	FOS	WC
Turkmenistan caracal	female	73.46	77.61	67.25
	male	75.77	70.54	68.52
Amur leopard cat	female	63.78	73.52	64.16
	male	68.26	74.88	67.32
Mean ± s.d.		$70.24^{a,b}$ ± 4.76	$74.14^{a,}$ ± 2.54	66.95^{b} ± 1.39

^{a,b}significantly different $P < 0.05$

TABLE 6. Fecal index score of three different beef-based carnivore diets with varying fiber sources: beet pulp (BP), cellulose/fructooligosaccharide 3:1 blend (FOS), and wood cellulose (WC) fed to two small (< 15 kg) felid species

Species	Animal	Dietary treatment		
		BP	FOS	WC
Turkmenistan	female	2.2	2.8	2.5
caracal	male	2.4	2.4	2.0
Amur	female	2.2	3.4	2.2
leopard cat	male	2.6	3.0	2.6
Mean		2.35	2.90	2.33

TABLE 7. Transit time (h) of three different beef-based carnivore diets with varying fiber sources: beet pulp (BP), cellulose/fructooligosaccharide 3:1 blend (FOS), and wood cellulose (WC) fed to two small (< 15 kg) felid species

Species	Animal	Dietary treatment		
		BP	FOS	WC
Turkmenistan	Female	24.0	24.0	24.0
Caracal	Male	24.0	24.0	24.0
Amur	Female	nd[1]	nd	nd
leopard cat	Male	24	48	33
Mean ± s.d.		24	32	27

[1]nd=not determined