

DIETS OFFERED TO MANED WOLVES (*CHRYSOCYON BRACHYURUS*) IN NORTH AMERICAN ZOOS: A REVIEW AND ANALYSIS

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Abstract

The maned wolf, a canid native to South America, has had a history of cystinuria and poor fecal consistency in North American institutions. Factors contributing to this may be related to feeding the species a primarily carnivorous diet, despite its omnivorous dietary habits under free-ranging conditions. To address cystinuria and fecal consistency, a commercially manufactured diet was fed to all maned wolves in North America. However, after a few years of use, some wolves demonstrated clinical signs of taurine and/or copper deficiencies. This unanticipated result led to a change to use of institution specific diets across the SSP population. The purpose of this project was to quantify, analyze and compare diets currently offered to the SSP population of maned wolves. Diet items offered were classified into groups and their distribution between institutions compared. Nutrients delivered in offered diets were calculated for each institution. These results demonstrate each of the 26 SSP institutions were feeding maned wolves diets differing in ingredients, quantity and nutrient composition.

Introduction

The maned wolf (*Chrysocyon brachyurus*), the largest South American canid, weighing approximately 23 kg, is classified as endangered by the Brazilian government and the United States Fish and Wildlife Service.³ Native to the grasslands and scrub forests of central South America, maned wolves are in the order Carnivora and family Canidae. Based on analyzed scats from wolves living in the wild, 49% of food items were animal material and 51% plant material.³ Based on those scats, the fruit *Solanum lycocarpum*, is present in the largest proportion of the consumed omnivorous diet of wild maned wolves.³ Locally the fruit, resembling large tomatoes, is called lobeira, which means fruit of the maned wolf.³ The diet of wild maned wolves differs slightly depending on season. During the dry season small mammals and foliage occurred more frequently in scats and during the wet season fruits and insects were consumed more often.³

In contrast with the species' omnivorous adaptations, maned wolves in captivity have been fed a primarily carnivorous diet. Such a feeding strategy has been associated with the development of cystinuria, also known as cystine urolithiasis.³ Cystinuria, literally meaning cystine in the urine, is an inherited defect of amino acid transport.⁶ The disease is associated with the absence, or ineffective transport, of some amino acids such as cystine as well as lysine, ornithine, and arginine.⁵ The disease contributes to ineffective amino acid absorption in the small intestine and kidney, which results in stone formation in the kidney, bladder, and urethra.^{1,6} Urinary tract infection and secondary rupture of the bladder can result from stone obstruction.¹ In previous studies of both captive and free-ranging maned wolves, 80% have the disorder.¹ Another issue affecting much of the captive maned wolf population in North America is poor fecal consistency.

Fecal consistency is not only a possible indication of changes in gut health, but creates challenges related to animal and enclosure cleanliness, vector control and aesthetics.

To address cystinuria and to improve fecal consistency, a commercially manufactured maintenance maned wolf diet was developed.⁵ This diet was adopted as a standard food to be fed to all maned wolves in North America. Unfortunately, an unanticipated effect of the diet contributed to taurine deficiency in several animals.⁴ The use of the standardized diet was discontinued. Following these events, most North American zoos housing maned wolves reverted to feeding their own diets, and at present time, each of the 26 zoos housing maned wolves feed diets that differ in ingredients and nutrient composition.

The objective of this project is to quantify, following a period of diet standardization, the diets currently offered to the North American maned wolf population and to compare and analyze the differences in nutrient content of the offered diets among institutions.

Methods

Animals

Seventy-eight (78) maned wolves from twenty-six (26) zoos across the United States were included in this project.

Data Collection

As an introduction to the project, each zoo was contacted by email in October of 2006, which explained the objectives and included a survey, and diet sheets: one completed example and one blank for each zoo to fill out for each specimen. In addition to this information, zoos were also asked to collect fecal samples and assign a consistency score for each of their animals based on a standardized canine fecal consistency scoring system⁷. Within a few weeks, each institution was contacted by phone to facilitate completion of the survey and diet sheets for each animal. Once all the daily diets were collected, a list of all relevant feed items was compiled. Commercial foods that were included in several diets were submitted to a commercial laboratory (Cumberland Valley Analytical Services, Inc, Maugansville Maryland) for amino acid analysis: arginine (ARG), histine (HIS), isoleucine (ILE), leucine (LEU), lysine (LYS), methionine (MET), phenylalanine (PHE), threonine (THR), tryptophan (TRP), valine (VAL), taurine (TAU), cysteine (CYS), glycine (GLY), alanine (ALA), serine (SER), tyrosine (TYR), ASP, GLU, PRO, hydroxyproline (HYPRO), hydroxylysine (HYLYS), Ornithine, Lanthionine). Manufactures were contacted to obtain missing nutrient information when possible. Remaining nutrient data was obtained from a range of references. Despite these efforts, there were several foods that have incomplete nutrient profiles.

Data Analysis

Energy, proximate analysis, plant cell wall constituents: acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose, hemicellulose, acid detergent (AD lignin); minerals: calcium (Ca), phosphorus (P), sodium (Na), potassium (K), sulfur (S), magnesium (Mg), chloride (Cl)

ion, copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), selenium (Se); and amino acid profiles (ARG, HIS, ILE, LEU, LYS, MET, PHE, THR, TRP, VAL, TAU, CYS, GLY, ALA, SER, TYR, ASP, GLU, PRO, HYPRO, HYLYS), for each feed item were entered into a diet analysis program.² Each animal's daily diet was analyzed according to the proportions of feed types (Table 1) and nutrients offered (Table 2).

Results and Discussion

Current diets offered to individual animals on an as-fed basis, organized by institution, are summarized in Table 1. On average the North American zoos are feeding 71.1% (by weight) commercial diets; ranging from 23.8% to 94.2%. Meat based commercial diets were an average of 12.7%, ranging from 0 to 94.2%. Prey is being fed on average as 9.2% of the diet, and ranging from 0 to 44.1%. Meats and eggs are being fed on average of 1.2% of the diet and ranging from 0 to 11.6% of the diet. The average of produce fed is 17% and ranges from 0 to 48% of the total daily diet. Miscellaneous items, such as oils, processed fruits and vegetables and meats, account for on average 2.5% of the diet and ranging from 0 to 13.7%.

Of the twenty-six institutions, 85% are feeding commercial diets at a minimum of 50% of the diet by weight; 88% are feeding some sort of prey on a regular basis; all but two institutions feed produce, with a majority feeding it on a daily basis. Only three institutions (11.5%) are currently feeding produce at a minimum of 30% of the diet, by weight. If we use this arbitrary threshold to designate what constitutes an omnivorous diet, then most SSP institutions are currently feeding a carnivorous diet.

In regards to fecal consistency of maned wolves reported, the mean score was 42 (range = 28 to 60). At one institution, fecal consistency scores reported for four individual animals fed the same diet ranged from 28 to 47 (mean = 34.25). It should be considered, that in addition to diet, factors such as health, activity and hydration may also contribute to fecal consistency.

The average nutrient composition of the diets offered to animals at each institution is summarized in Table 2. The nutrient composition of an experimental diet and the nutrient requirements for domestic dogs are provided for comparison (Table 2).^{4,7}

Currently, each institution housing maned wolves feeds a different diet, with some individual institutions feeding more than one diet. There are both positive and negative aspects of this type of diet management within a small population. Since maned wolves in the United States are managed under a species survival plan (SSP), individuals are moved frequently satisfy population management recommendations. Application of a standardized diet would minimize the stress related to diet transition in conjunction with adaptation to a new environment, as animals are moved between zoos. Additionally, a standard diet would remove a 'variable' from the population for future epidemiological studies. In contrast, the risks associated with a single, standardized diet that may not be optimal for the nutrient requirements of the species could lead to a population wide nutritional imbalance.

However, an intermediate course of action could be beneficial. The standardization of a single, nutritionally balance component fed at a minimum recommended level of intake across the entire population could provide the positive aspects of both scenarios; this component may be a dog

food, a canine complete diet, or similar food. The balance of the diet could be selected by the individual institutions based on regional availability, management and other factors. Regardless, it is essential that the entire diet meet the projected, unique requirements of the species.

Since the diet analysis results presented are sometimes based on incomplete nutrient profiles, it is difficult to determine if the values are truly representative of the nutrient composition of the offered diet. However, there are several institutions' diets that have complete nutrient profiles and are valuable to analyzing the wolves' diets. For example, the fact that cysteine and methionine levels were found to be below recommended NRC levels, may be due to the absence of information on cysteine and methionine data of some feed items. All other values, on average, met the NRC requirements for domestic dogs, and were comparable to the test diet developed by Childs-Sanford and Angel.⁴

Conclusions

1. The North American maned wolf population was historically fed a single, standardized diet and is now offered more than 26 individual diets across 26 institutions.
2. Each diet differs in ingredients, quantities and nutrient composition.
3. Despite variability in dietary nutrient composition across the SSP, all diets exceed the crude protein requirement for domestic dogs (NRC), and nearly all exceed the crude protein content of the experimental diet.⁴ Patterns of excess and deficiency are observed among other nutrients; however, the absence of data for specific foods limits our ability to make population-wide conclusions.
4. The benefits of one or more standardized components of the diet to be fed across the entire SSP population should be critically evaluated.

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Table 1. Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP			
	MEAN	ALEXANDRI	AUDUBON	BATONROUG
Commercial	71.108	42.23	68.31	47.21
Dry	55.771	42.23	56.79	47.21
Canned	2.675	0	11.52	0
Meat-based	12.665	0	0	0
Prey	9.228	10.56	10.28	0
Mammalian	5.7	10.56	9.1	0
Avian	2.511	0	1.18	0
Fish	0.443	0	0	0
Insect	0.575	0	0	0
Meats, Eggs	1.188	4.97	0	0
Horse	0	0	0	0
Game	0.349	0	0	0
Eggs	0.839	4.97	0	0
Produce	16.974	42.23	21.41	48.02
Misc	2.478	0	0	4.775
Fecal Scores				
Animal 1		38	50	37
Animal 2		38	50	37
Animal 3				
Animal 4				
Average	42	38	50	37

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 1 (cont'd). Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP			
	MEAN	BIRMINGHA	BRIDGEPRT	BUFFALO
Commercial	71.108	85.06	76.07	47.14
Dry	55.771	78.905	76.07	47.14
Canned	2.675	0	0	0
Meat-based	12.665	6.155	0	0
Prey	9.228	4.575	0	24.17
Mammalian	5.7	4.575	0	22.215
Avian	2.511	0	0	0
Fish	0.443	0	0	1.305
Insect	0.575	0	0	0.65
Meats, Eggs	1.188	0	0	0
Horse	0	0	0	0
Game	0.349	0	0	0
Eggs	0.839	0	0	0
Produce	16.974	5.945	23.93	15.005
Misc	2.478	4.42	0	13.685
Fecal Scores				
Animal 1		31	31.25	60
Animal 2		49		56
Animal 3				
Animal 4				
Average	42	40	31.25	58

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 1 (cont'd). Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP			
	MEAN	DENVER	DICKERSON	FOSSILRIM
Commercial	71.108	90.62	78.31	74.615
Dry	55.771	90.62	54.22	28.18
Canned	2.675	0	0	25.055
Meat-based	12.665	0	24.09	21.38
Prey	9.228	8.93	0	10.595
Mammalian	5.7	0	0	0
Avian	2.511	8.93	0	10.595
Fish	0.443	0	0	0
Insect	0.575	0	0	0
Meats, Eggs	1.188	0	0	0
Horse	0	0	0	0
Game	0.349	0	0	0
Eggs	0.839	0	0	0
Produce	16.974	0	21.69	7.465
Misc	2.478	0.45	0	7.33
Fecal Scores				
Animal 1		50		42
Animal 2		38		49
Animal 3				
Animal 4				
Average	42	44		45.5

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 1 (cont'd). Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP			
	MEAN	HOUSTON	JOHN BALL	LITTLEROC
Commercial	71.108	67.12	75.13	72.81
Dry	55.771	36.32	75.13	72.81
Canned	2.675	23.57	0	0
Meat-based	12.665	7.23	0	0
Prey	9.228	2.59	3.96	2.77
Mammalian	5.7	2.59	3.96	0
Avian	2.511	0	0	0
Fish	0.443	0	0	2.77
Insect	0.575	0	0	0
Meats, Eggs	1.188	0.55	0	1.39
Horse	0	0	0	0
Game	0.349	0	0	0
Eggs	0.839	0.55	0	1.39
Produce	16.974	29.74	19.36	23.03
Misc	2.478	0	1.55	0
Fecal Scores				
Animal 1				
Animal 2				
Animal 3				
Animal 4				
Average	42			

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 1 (cont'd). Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP			
	MEAN	LOSANGELE	LOUISVILL	MANHATTAN
Commercial	71.108	23.81	94.19	56.93
Dry	55.771	23.81	0	56.92
Canned	2.675	0	0	0
Meat-based	12.665	0	94.19	0
Prey	9.228	44.05	0.885	14.42
Mammalian	5.7	10.71	0.505	6.98
Avian	2.511	19.05	0.38	0
Fish	0.443	0	0	7.44
Insect	0.575	14.29	0	0
Meats, Eggs	1.188	0	0	6.51
Horse	0	0	0	0
Game	0.349	0	0	0
Eggs	0.839	0	0	6.51
Produce	16.974	32.14	4.925	22.14
Misc	2.478	0	0	0
Fecal Scores				
Animal 1				
Animal 2				
Animal 3				
Animal 4				
Average	42			

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 1 (cont'd). Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP	MONTGOMR	NYP-CRC	NYP-WASH
	MEAN	Y		
Commercial	71.108	54.87	76.778	85.65
Dry	55.771	54.88	71.133	79.05
Canned	2.675	0	5.13	4.28
Meat-based	12.665	0	0.598	2.32
Prey	9.228	19.5	8.568	2.32
Mammalian	5.7	19.5	8.568	2.32
Avian	2.511	0	0	0
Fish	0.443	0	0	0
Insect	0.575	0	0	0
Meats, Eggs	1.188	0	0.472	0.4
Horse	0	0	0	0
Game	0.349	0	0	0
Eggs	0.839	0	0.472	0.4
Produce	16.974	25.63	13.223	11.63
Misc	2.478	0	0.958	0
Fecal Scores				
Animal 1				
Animal 2				
Animal 3				
Animal 4				
Average	42			

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 1 (cont'd). Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP			
	MEAN	OKLAHOMA	OMAHA	PHOENIX
Commercial	71.108	92.71	92.05	88.425
Dry	55.771	2.06	89.24	8.56
Canned	2.675	0	0	0
Meat-based	12.665	90.65	2.81	79.865
Prey	9.228	3.34	3.74	3.68
Mammalian	5.7	3.34	3.74	3.68
Avian	2.511	0	0	0
Fish	0.443	0	0	0
Insect	0.575	0	0	0
Meats, Eggs	1.188	0	4.21	0
Horse	0	0	0	0
Game	0.349	0	0	0
Eggs	0.839	0	4.21	0
Produce	16.974	3.95	0	7.89
Misc	2.478	0	0	0
Fecal Scores				
Animal 1				
Animal 2				
Animal 3				
Animal 4				
Average	42			

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 1 (cont'd). Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP			
	MEAN	ROLLING H	SEDGWICK	WCSRC
Commercial	71.108	88.18	77.49	58.21
Dry	55.771	88.18	77.49	58.21
Canned	2.675	0	0	0
Meat-based	12.665	0	0	0
Prey	9.228	0.24	9.16	15.06
Mammalian	5.7	0	1.96	14.93
Avian	2.511	0.24	7.2	0.13
Fish	0.443	0	0	0
Insect	0.575	0	0	0
Meats, Eggs	1.188	0	0.78	0
Horse	0	0	0	0
Game	0.349	0	0	0
Eggs	0.839	0	0.78	0
Produce	16.974	11.58	8.27	25.15
Misc	2.478	0	4.3	1.58
Fecal Scores				
Animal 1				28
Animal 2				31
Animal 3				31
Animal 4				47
Average	42			34.25

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 1 (cont'd). Mean proportion of foods offered, and fecal scores, by institution, of maned wolves (*Chrysocyon brachyurus*), in North American zoos, expressed by weight (as-fed basis).^{1,2}

FEED	SSP MEAN	WINSTON	YULEE
Commercial	71.108	58.37	76.53
Dry	55.771	58.37	76.53
Canned	2.675	0	0
Meat-based	12.665	0	0
Prey	9.228	16.68	19.856
Mammalian	5.7	16.68	2.281
Avian	2.511	0	17.574
Fish	0.443	0	0
Insect	0.575	0	0
Meats, Eggs	1.188	11.6	0
Horse	0	0	0
Game	0.349	9.08	0
Eggs	0.839	2.52	0
Produce	16.974	13.35	3.614
Misc	2.478	0	0
Fecal Scores			
Animal 1			
Animal 2			
Animal 3			
Animal 4			
Average	42		

¹Commercial includes foods that are manufactured, in various forms, and formulated to be nutritionally complete. Prey includes whole animal(s) offered as food. Meats include portions of whole animals that alone are not nutritionally complete. Produce includes commercially available plant materials, including fresh fruits and vegetables. Some may be modified prior to feeding, including cooking.

² Ralston Purina Company. 2000. Fecal Scoring System for Dogs.

Table 2 (cont'd). Nutrient requirements of domestic dogs (NRC, 2006), nutrient composition of an experimental diet for maned wolves (Childs-Sanford and Angel, 2006), and calculated nutrient composition of diets offered to maned wolves (*Chrysocyon brachyurus*), in North American zoos, all data, except moisture, expressed on a dry-matter basis.^{1,2}

NUTRIENT	NRC- DOG ³	EXP DIET ⁴	ALEXAND RI	AUDUBON	BATONRO UG
Moisture, %	-	9.5	46.13	39.93	43.2
Crude protein, %	10	20.44	26.52	19.51	23.33
Lysine, %	0.35	1.05	1.439	1.451	1.48
Methionine, %	0.33	0.29	0.558	0.635	0.494
Cystine, %	0.32	0.23	0.388	0.273	0.321
Taurine, %	-	0.33	<u>0.118</u>	<u>0.214</u>	0.099
Fat, %	5.5	17.68	15.81	13.73	14.9
CHO, %	-	-	47.18	58.7	47.19
Crude fiber, %	-	7.18	1.1	1.29	2.48
Ash, %	-	8.03	6.18	4.37	6.015
ME, kcal kg ⁻¹	-	3.9	<u>0.77</u>	4.03	4.29
Ca (%)	0.3	1.55	1.158	0.724	1.128
P (%)	0.3	0.88	0.804	0.552	0.796
K (%)	0.4	0.88	0.814	0.761	0.866
Na (%)	0.04	0.33	0.329	0.29	0.287
Mg (%)	0.06	0.13	0.104	0.05	0.101
Cu (ppm)	0.6	13	18.5	13.8	14.5
Fe (ppm)	3	450	206.7	237.9	276.55
Mn (ppm)	0.5	63	64.1	22.2	65.85
Zn (ppm)	6	180	198.1	195.9	197.15

¹Calculated nutrient composition may be influenced by missing and incomplete nutrient profiles.

²Values underlined are based on incomplete nutrient profiles.

³National Research Council. 2006. *Nutrient Requirements of Dogs and Cats*. Washington, DC: The National Academies Press.

⁴Childs-Sanford, S., & Angel, C. 2006. *Zoo Biology* 25(2): 87-100.

Table 2 (cont'd). Nutrient requirements of domestic dogs (NRC, 2006), nutrient composition of an experimental diet for maned wolves (Childs-Sanford and Angel, 2006), and calculated nutrient composition of diets offered to maned wolves (*Chrysocyon brachyurus*), in North American zoos, all data, except moisture, expressed on a dry-matter basis.^{1,2}

NUTRIENT	NRC- DOG³	EXP DIET⁴	BIRMING HA	BRIDGEPR T	BUFFALO
Moisture, %	-	9.5	21.085	26.41	42.9
Crude protein, %	10	20.44	26.87	21.92	23.28
Lysine, %	0.35	1.05	1.645	1.251	1.383
Methionine, %	0.33	0.29	0.538	<u>0.002</u>	0.447
Cystine, %	0.32	0.23	0.405	<u>0.003</u>	0.278
Taurine, %	-	0.33	<u>0.111</u>	0.093	<u>0.107</u>
Fat, %	5.5	17.68	17.25	12.54	13.635
CHO, %	-	-	26.975	51.4	52.725
Crude fiber, %	-	7.18	3.85	5.34	3.14
Ash, %	-	8.03	0.425	8.97	6.86
ME, kcal kg ⁻¹	-	3.9	<u>2.25</u>	3.84	4.085
Ca (%)	0.3	1.55	1.263	1.656	0.898
P (%)	0.3	0.88	1.027	1.452	0.618
K (%)	0.4	0.88	0.901	0.917	1.197
Na (%)	0.04	0.33	0.46	0.31	0.355
Mg (%)	0.06	0.13	0.129	0.213	0.094
Cu (ppm)	0.6	13	35.05	12.6	14.05
Fe (ppm)	3	450	310.3	352.1	220.35
Mn (ppm)	0.5	63	30.907	88.2	11.35
Zn (ppm)	6	180	229.1	258.8	211.5

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³National Research Council. 2006. *Nutrient Requirements of Dogs and Cats*. Washington, DC: The National Academies Press.

⁴Childs-Sanford, S., & Angel, C. 2006. *Zoo Biology* 25(2): 87-100.

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NUTRIENT	NRC- DOG ³	EXP DIET ⁴	DENVER	DICKERSO N	FOSSILRI M
Moisture, %	-	9.5	15.7	39.68	53.855
Crude protein, %	10	20.44	29.99	31.18	30.53
Lysine, %	0.35	1.05	1.971	<u>0.016</u>	<u>1.23</u>
Methionine, %	0.33	0.29	0.635	<u>0.005</u>	<u>0.342</u>
Cystine, %	0.32	0.23	0.428	<u>0.004</u>	<u>0.19</u>
Taurine, %	-	0.33	0.129	<u>0</u>	<u>0.072</u>
Fat, %	5.5	17.68	19.76	14.34	16.6
CHO, %	-	-	32.09	45.04	38.64
Crude fiber, %	-	7.18	2.365	4.36	1.73
Ash, %	-	8.03	6.975	7.77	9.2
ME, kcal kg ⁻¹	-	3.9	4.325	4.78	3.805
Ca (%)	0.3	1.55	1.493	0.904	<u>1.683</u>
P (%)	0.3	0.88	1.028	0.874	0.955
K (%)	0.4	0.88	0.862	<u>0.084</u>	<u>1.028</u>
Na (%)	0.04	0.33	0.385	0.402	<u>0.482</u>
Mg (%)	0.06	0.13	0.111	0.095	<u>0.082</u>
Cu (ppm)	0.6	13	17.3	<u>0.4</u>	<u>13</u>
Fe (ppm)	3	450	345.95	<u>1.4</u>	<u>205.4</u>
Mn (ppm)	0.5	63	81.8	<u>1.1</u>	<u>16.45</u>
Zn (ppm)	6	180	255.6	<u>0.7</u>	<u>163.5</u>

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NUTRIENT	NRC- DOG ³	EXP DIET ⁴	HOUSTON	JOHN BALL	LITTLERO C
Moisture, %	-	9.5	49.6	23.73	28.18
Crude protein, %	10	20.44	24.51	27.28	24.43
Lysine, %	0.35	1.05	<u>0.448</u>	1.367	<u>0.031</u>
Methionine, %	0.33	0.29	<u>0.124</u>	0.584	<u>0.015</u>
Cystine, %	0.32	0.23	<u>0.085</u>	0.384	<u>0.009</u>
Taurine, %	-	0.33	<u>0.009</u>	0.148	<u>0</u>
Fat, %	5.5	17.68	17.23	19.73	14.86
CHO, %	-	-	49.3	41.08	54.82
Crude fiber, %	-	7.18	2.9	1.07	1.56
Ash, %	-	8.03	<u>2.24</u>	6.34	4.57
ME, kcal kg ⁻¹	-	3.9	4.22	0.3	0.3
Ca (%)	0.3	1.55	1.01	1.253	0.68
P (%)	0.3	0.88	0.775	0.858	0.612
K (%)	0.4	0.88	0.64	0.607	0.664
Na (%)	0.04	0.33	0.259	0.372	0.267
Mg (%)	0.06	0.13	0.101	0.094	<u>0.004</u>
Cu (ppm)	0.6	13	<u>1</u>	22.1	<u>0.3</u>
Fe (ppm)	3	450	<u>12.1</u>	251.8	<u>2.1</u>
Mn (ppm)	0.5	63	<u>1.1</u>	78.4	<u>0.6</u>
Zn (ppm)	6	180	<u>4.1</u>	242	<u>1.3</u>

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NUTRIENT	NRC- DOG ³	EXP DIET ⁴	LOSANGE LE	LOUISVIL L	MANHATT AN
Moisture, %	-	9.5	58.81	68.49	37.89
Crude protein, %	10	20.44	36.64	58.26	29.78
Lysine, %	0.35	1.05	<u>1.073</u>	3.629	1.485
Methionine, %	0.33	0.29	<u>0.428</u>	1.448	0.605
Cystine, %	0.32	0.23	<u>0.308</u>	0.669	0.406
Taurine, %	-	0.33	<u>0.087</u>	0.299	<u>0.137</u>
Fat, %	5.5	17.68	17.58	25.615	18.75
CHO, %	-	-	34.44	3.255	39.94
Crude fiber, %	-	7.18	1.24	3.395	<u>1.06</u>
Ash, %	-	8.03	7.36	5.88	6.53
ME, kcal kg ⁻¹	-	3.9	1.1	2.85	0.49
Ca (%)	0.3	1.55	1.648	1.968	1.279
P (%)	0.3	0.88	0.705	1.66	0.909
K (%)	0.4	0.88	0.784	0.945	0.652
Na (%)	0.04	0.33	0.295	0.663	0.389
Mg (%)	0.06	0.13	0.097	0.124	0.098
Cu (ppm)	0.6	13	17.3	9.85	20.7
Fe (ppm)	3	450	239.9	227.6	236.5
Mn (ppm)	0.5	63	53.4	25.85	73.3
Zn (ppm)	6	180	349.9	90.65	230

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NUTRIENT	NRC- DOG ³	EXP DIET ⁴	MONTGOMRY	NZP- CRC	NZP- WASH
Moisture, %	-	9.5	40.21	29.103	24.27
Crude protein, %	10	20.44	25.26	29.818	29.4
Lysine, %	0.35	1.05	1.458	1.855	1.795
Methionine, %	0.33	0.29	<u>0.115</u>	0.607	0.588
Cystine, %	0.32	0.23	<u>0.108</u>	0.413	0.389
Taurine, %	-	0.33	<u>0.083</u>	<u>0.121</u>	0.128
Fat, %	5.5	17.68	13.48	19.348	19.47
CHO, %	-	-	47.07	32.977	33.18
Crude fiber, %	-	7.18	<u>4.84</u>	2.375	2.45
Ash, %	-	8.03	8.97	7.023	6.98
ME, kcal kg ⁻¹	-	3.9	3.98	4.385	4.35
Ca (%)	0.3	1.55	1.841	1.531	1.463
P (%)	0.3	0.88	1.454	1.032	1.023
K (%)	0.4	0.88	0.92	0.904	0.896
Na (%)	0.04	0.33	0.318	0.375	0.379
Mg (%)	0.06	0.13	0.199	0.109	0.109
Cu (ppm)	0.6	13	12.4	16.883	17.3
Fe (ppm)	3	450	360.6	344.733	341
Mn (ppm)	0.5	63	79	63.985	79.7
Zn (ppm)	6	180	237.4	246.4	253

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NUTRIENT	NRC-DOG ³	EXP DIET ⁴	OKLAHOMA	OMAHA	PHOENIX
Moisture, %	-	9.5	65.78	16.49	61.925
Crude protein, %	10	20.44	52.72	29.8	46.955
Lysine, %	0.35	1.05	<u>0.105</u>	<u>0.153</u>	<u>0.414</u>
Methionine, %	0.33	0.29	<u>0.034</u>	<u>0.05</u>	<u>0.133</u>
Cystine, %	0.32	0.23	<u>0.032</u>	<u>0.038</u>	<u>0.11</u>
Taurine, %	-	0.33	<u>0</u>	<u>0.003</u>	<u>0</u>
Fat, %	5.5	17.68	24.38	18.42	22.545
CHO, %	-	-	4.51	0.13	4.88
Crude fiber, %	-	7.18	0.19	3.24	1.275
Ash, %	-	8.03	6.7	0.27	5.55
ME, kcal kg ⁻¹	-	3.9	4.49	0.12	3.405
Ca (%)	0.3	1.55	<u>0.151</u>	1.131	<u>0.353</u>
P (%)	0.3	0.88	<u>1.068</u>	0.908	1.064
K (%)	0.4	0.88	<u>0.052</u>	<u>0.033</u>	<u>0.222</u>
Na (%)	0.04	0.33	<u>0.026</u>	<u>0.02</u>	<u>0.128</u>
Mg (%)	0.06	0.13	<u>0.012</u>	<u>0.004</u>	<u>0.031</u>
Cu (ppm)	0.6	13	<u>0.4</u>	<u>0.2</u>	<u>9</u>
Fe (ppm)	3	450	<u>14.5</u>	<u>5.3</u>	<u>56.8</u>
Mn (ppm)	0.5	63	<u>0.3</u>	<u>0.5</u>	<u>12.4</u>
Zn (ppm)	6	180	<u>2.4</u>	<u>2.9</u>	<u>57.45</u>

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NUTRIENT	NRC- DOG ³	EXP DIET ⁴	ROLLING H	SEDGWICK	WCSRC
Moisture, %	-	9.5	17.89	22.3	33.88
Crude protein, %	10	20.44	28.62	28.32	23.47
Lysine, %	0.35	1.05	1.845	1.445	<u>0.356</u>
Methionine, %	0.33	0.29	0.604	0.602	<u>0.085</u>
Cystine, %	0.32	0.23	0.4	0.399	<u>0.07</u>
Taurine, %	-	0.33	0.129	0.15	<u>0</u>
Fat, %	5.5	17.68	18.96	21.37	17.25
CHO, %	-	-	34.4	38.48	51.9
Crude fiber, %	-	7.18	2.48	0.98	2.04
Ash, %	-	8.03	6.85	6.38	<u>1.06</u>
ME, kcal kg ⁻¹	-	3.9	4.43	0.38	3.8
Ca (%)	0.3	1.55	1.453	1.254	1.091
P (%)	0.3	0.88	1.004	0.875	0.74
K (%)	0.4	0.88	0.89	0.595	0.681
Na (%)	0.04	0.33	0.365	0.393	0.259
Mg (%)	0.06	0.13	0.109	0.095	0.102
Cu (ppm)	0.6	13	17.3	22.2	<u>0.9</u>
Fe (ppm)	3	450	343.2	250.7	<u>12.2</u>
Mn (ppm)	0.5	63	81.9	79	<u>1.9</u>
Zn (ppm)	6	180	253.7	245.8	<u>7.1</u>

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NUTRIENT	NRC- DOG ³	EXP DIET ⁴	WINSTON	YULEE
Moisture, %	-	9.5	35.2	24.15
Crude protein, %	10	20.44	33.38	30.6
Lysine, %	0.35	1.05	1.503	1.67
Methionine, %	0.33	0.29	0.644	0.658
Cystine, %	0.32	0.23	0.368	0.448
Taurine, %	-	0.33	<u>0</u>	0.152
Fat, %	5.5	17.68	16.7	18.7
CHO, %	-	-	38.97	38.3
Crude fiber, %	-	7.18	<u>2.51</u>	0.93
Ash, %	-	8.03	7.66	6.74
ME, kcal kg ⁻¹	-	3.9	4.44	0.043
Ca (%)	0.3	1.55	1.363	1.34
P (%)	0.3	0.88	1.087	0.93
K (%)	0.4	0.88	0.684	0.62
Na (%)	0.04	0.33	0.412	0.42
Mg (%)	0.06	0.13	0.147	0.1
Cu (ppm)	0.6	13	48.6	22.5
Fe (ppm)	3	450	199.1	257.5
Mn (ppm)	0.5	63	45.8	80.1
Zn (ppm)	6	180	159.1	251.3

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