Timely Topics in Nutrition

Nutritional adequacy of two vegan diets for cats

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People have a long history of consuming vegetarian diets, and the population of humans who are vegetarians appears to be growing. In a 2002 poll, 4% of Americans considered themselves to be vegetarians.[1] However, vegetarianism comprises a wide range of dietary beliefs and practices. Some of the more common types include ovovegetarians, who eat vegetables and eggs, and lactovegetarians, who eat vegetables and dairy products. The strictest form of vegetarianism is veganism. A vegan excludes meat, seafood, eggs, dairy products, and all other animal products from the diet. Reasons for adopting any of the many vegetarian diets include health as well as religious and ethical concerns. Ethical beliefs are a common reason for people to adopt a vegan lifestyle and to eliminate all animal products from their diet. Some so wish to distance themselves from any sort of animal consumption that they elect to feed their dogs and cats a diet free of animal products. To our knowledge, the health and safety of vegan diets has not been determined for dogs or cats, and this issue is of particular concern for cats.

Cats Are Carnivores

Some books, advertisements, and Web sites claim that cats can safely be maintained on a plant-only diet despite the anatomic, physiologic, biochemical, metabolic, and enzymatic adaptations that reflect the status of cats as obligate carnivores.[2-5] Compared with dogs, cats have a shorter gastrointestinal tract and fewer premolars and molars, and they lack fissured crowns, which is consistent with their carnivorous nature.[2] In contrast to dogs, cats do not like the taste of sugars, which are less common in animal tissues.[2,4]

As strict carnivores, cats have a limited ability to alter the activity of various enzymes in response to the composition of their diet.[2-6] The most striking example of this is the enzymes of the urea cycle, which are not adaptive in cats but are adaptive in dogs and most other species.[2-6] The urea cycle disposes of amino groups that accumulate secondary to amino acid catabolism, and continuous activity of the urea cycle maximally protects cats against hyperammonemia. However, the cost is an inability to conserve nitrogen when consuming a low-protein diet. Other examples of metabolic adaptations include a lack of salivary amylase, reduced activities of pancreatic and intestinal amylase (compared with activities found in dogs), reduced glucokinase activity, a lack of fructokinase activity, and reduced activity of small intestinal disaccharidases.[2-5]

Necessary Dietary Components for Cats

When animal tissues are eliminated from the diet of obligate carnivores, the potential for nutritional deficiencies increases because specific essential nutrients typically are scarce or limited in plant material. Some nutrients are of particular concern in a plant-based diet for cats.

Cats require dietary taurine. Cats conjugate bile acids into bile salts exclusively by the use of taurine, whereas most other species can use glycine for conjugation when taurine concentrations are low.[7] Within the intestinal lumen, microbial degradation further increases taurine loss.[8] These issues, coupled with a low rate of hepatic synthesis, result in the need for adequate amounts of taurine in the diet of cats.[2-4,8] Taurine must be supplemented in plant-based diets because it is found in low amounts in nonanimal tissues.

In contrast to dogs, cats synthesize limited amounts of arachidonic acid from linoleic acid because cats have low amounts of hepatic Δ-6 desaturase.[2,3] Thus, arachidonic acid, which is found in animal tissues and some algal biomass, is required in the diet of felids.[2,3,9]

Cats cannot synthesize sufficient niacin from tryptophan because the intermediate metabolite is readily degraded.[2,4,9] Furthermore, niacin is less ample in plant tissues. Cobalamin is produced by microbes and is scarce in plants; any vegan diet will require supple-

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mentation of cobalamin. Pyroxidine is a coenzyme for transaminases and is needed in higher amounts by cats because of their increased protein catabolism.[2-4,9]

Cats cannot synthesize vitamin A (retinol) from beta-carotene, the plant-derived precursor of vitamin A.[2-4,9] Thus, preformed retinol must be provided in the diet of cats. Cats also require a dietary source of vitamin D, and plant-based ingredients contain little vitamin D. Vitamin D can be added to diets as a supplement, but the form is important because cats use cholecalciferol more efficiently than ergocalciferol.[2,9,10]

Sulfur-containing amino acids such as methionine and cysteine are needed in greater amounts by cats and are often limiting, especially when cats are fed plant-based diets.[2-4,9] This higher requirement may be needed for synthesis of taurine and felinine as well as hair growth.[2-4,9]

Arginine is an essential amino acid in the diet of cats because of its function in the urea cycle and the reduced ability of cats to synthesize arginine precursors.[2-4,9] Arginine provides a required intermediate in the urea cycle, and the lack of dietary arginine causes hyperammonemia and hepatic encephalopathy.[2-4,9] Arginine is typically found in low amounts in plant-based diets.

Cats require dietary lysine. Lysine is typically limited in the diet when grains are the only major source of protein.[4,9]

Feeding vegan diets to cats can only be justified when results of diet analysis and feeding trials document that these diets are nutritionally balanced and do not result in deficiencies when fed to cats. In a European field study[a] of vegetarian foods fed to cats, nutrients commonly found to be low in the diets included taurine, calcium, phosphorus, vitamin D, vitamin B_{12}, vitamin A, and arachidonic acid.

Analysis of Vegan Diets

To our knowledge, no analysis of vegan foods formulated for cats and commercially available in the United States has been reported. Therefore, our intent was to analyze 2 commercially available vegan diets to assess whether they met the minimum nutrient amounts cited in the **Association of American Feed Control Officials (AAFCO)** Cat Food Nutrient Profiles.[11]

Two vegan diets (diets A[b] and B[c]) were analyzed for key nutrients. These diets were chosen on the basis that they were readily available to consumers and claim to be nutritionally complete for cats. Ingredients listed for diet A were brewer's yeast (pH adjusted), vital wheat gluten, *Ascophyllum nodosum* (source of arachidonate), nonaluminum baking powder, calcium carbonate, dicalcium phosphate, taurine, DL-methionine, choline chloride, vitamin E (DL-alphatocopheryl acetate), zinc oxide, vitamin A acetate, vitamin B_{12}, and ergocalciferol (vitamin D_2). Ingredients listed for diet B were filtered water sufficient for processing, peas, potatoes, brown rice, carrots, wheat germ, oat groats, dicalcium phosphate, soybean oil, brewer's dried yeast, DL-methionine, L-taurine, guar gum, sea kelp, DL-alpha tocopherol acetate (vitamin E), vitamin A acetate, ergocalciferol (vitamin D_2), choline chloride, ferrous sulfate, zinc oxide, manganese sulfate, riboflavin supplement (vitamin B_2), thiamine mononitrate, pyridoxine hydrochloride, folic acid, biotin, vitamin B_{12} supplement, sodium selenate, and arachidonic acid.

Claims were made that diet A, when prepared in accordance with the manufacturer's instructions, met nutritional requirements according to the AAFCO Cat Food Nutrient Profile for adult maintenance. Diet B was a ready-to-serve canned food that, according to the label, was formulated to meet the nutritional levels established by the AAFCO Cat Food Nutrient Profiles for all life stages. That is, the claim was that diet B would meet the nutritional profiles for adult maintenance as well as growth and reproduction.

Diet A was prepared by meticulously adhering to the company's directions. Diet A was prepared by one of the investigators (CMG) in her home by use of the manufacturer's supplement mix and specified ingredients (ie, oil, flour, and tomato paste). A sample of the prepared diet was collected and submitted for analysis. Diet B was submitted for analysis as purchased (ie, an unopened can). Both diets were submitted to a commercial laboratory[d] for analysis. Because of the financial constraints of this study, a single sample of each diet was submitted for analysis and only those nutrients considered most likely to be a problem in a vegetarian diet were analyzed. Personnel at the laboratory were not aware of the product because all labels were removed and no indication of brand was provided. The resulting values were compared to minimum values from the 2004 AAFCO Cat Food Nutrient Profiles.[11]

Results of Dietary Analysis

Results of analysis of the 2 vegan diets were compared with the AAFCO Cat Food Nutrient Profile for adult maintenance (**Table 1**). Both diets had multiple nutrient deficiencies. Diet B was low in protein (62 g/1,000 kcal), and some amino acids were in amounts less than those cited for the AAFCO adult minimum amounts. Both diets contained less than the AAFCO minimum amounts for methionine and taurine. Diet A also was low in arginine and lysine content. Of particular concern was the low taurine content in both diets. Assuming that diet A should be considered similar to an extruded diet, the AAFCO minimum taurine concentration would be 0.25 g/1,000 kcal; however, diet A contained only 0.06 g of taurine/1,000 kcal (< 25% of the AAFCO minimum). The AAFCO minimum amount of taurine for canned food is 0.50 g/1,000 kcal, but diet B (a canned food) contained < 0.09 g of taurine/1,000 kcal (< 20% of the AAFCO minimum).

Although crude fat and linoleic acid contents of both diets were greater than the AAFCO minimums, dietary arachidonic acid concentration in each diet was less than the AAFCO minimum for adult maintenance (Table 1). Diet A contained < 0.02 g of arachidonic acid/1,000 kcal, and diet B contained < 0.04 g of arachidonic acid/1,000 kcal, whereas the AAFCO minimum was 0.05 g of arachidonic acid/1,000 kcal. The amounts of calcium and phosphorus in diet B were less than the AAFCO minimum for adult maintenance. The amount of vitamin A in diet B (< 391 U/1,000 kcal)

Table 1—Nutrient analysis of 2 commercial vegan diets formulated for cats and the Association of American Feed Control Officials (AAFCO) Cat Food Nutrient Profiles for adult maintenance.[11]

Nutrient	Diet A	Diet B	AAFCO Minimum	AAFCO Maximum
Crude protein(g)	78	62	65	NA
Amino acids				
Arginine (g)	2.52	3.64	2.60	NA
Cystine (g)	1.47	0.62	NA	NA
Histidine (g)	1.38	1.15	0.78	NA
Isoleucine (g)	2.74	2.22	1.30	NA
Leucine (g)	4.78	3.73	3.10	NA
Lysine (g)	1.88	2.93	2.08	NA
Methionine (g)	1.24	0.80	1.55	3.75
Methionine plus cystine (g)	2.71	1.42	2.75	NA
Phenylalanine (g)	3.54	2.66	1.05	NA
Phenylalanine plus tyrosine (g)	5.64	4.35	2.20	NA
Taurine (g)	0.06	< 0.09*	0.25 and 0.50†	NA
Threonine (g)	2.41	2.04	1.83	NA
Tryptophan (g)	0.94	0.71	0.40	NA
Tyrosine (g)	2.1	1.69	NA	NA
Valine (g)	3.10	2.49	1.55	NA
Crude fat (g)	24.4	37.5	22.5	NA
Linoleic acid (g)	4.12	9.10	1.25	NA
Arachidonic acid (g)	< 0.02*	< 0.04*	0.05	NA
Minerals				
Calcium (g)	2.1	0.1	1.5	NA
Phosphorus (g)	1.44	0.69	1.25	NA
Selenium (mg)	1.86	0.12	0.03	NA
Vitamin A (U)	164,553	< 391*	1,250	187,500
Niacin (mg)	20	10	15	NA
Pyridoxine (mg)	0.9	0.7	1.0	NA
Vitamin B_{12} (mg)	0.083	0.004	0.005	NA

Values reported are per 1,000 kcal.
*When the commercial laboratory reported a value of less than the value indicated, the value indicated was used in nutrient calculations. Although the actual value could not be reported for these nutrients, it was not greater than the value indicated. †The AAFCO minimum is 0.25 g/1,000 kcal for extruded foods formulated for cats and 0.50 g/1,000 kcal for canned foods formulated for cats.
NA = Not applicable because a minimum or maximum value has not been established for these nutrients.

also was less than the AAFCO minimum for adult maintenance, but the amount of vitamin A in diet A (164,553 U/1,000 kcal) was near the AAFCO maximum of 187,500 U of vitamin A/1,000 kcal. For B vitamins in the 2 diets, the amount of vitamin B_6 (pyridoxine) in both diets was less than the AAFCO minimum, and niacin and vitamin B_{12} contents were low in diet B.

Diet B had a label claim that it met the nutritional values established by the AAFCO Cat Food Nutrient Profiles for all life stages (ie, adult maintenance as well as growth and reproduction). Therefore, results of the analysis of this diet were compared with the AAFCO profiles for growth and reproduction of cats (**Table 2**). For this comparison, diet B contained less than the AAFCO minimum amounts of crude protein, lysine, methionine, taurine, arachidonic acid, calcium, phosphorus, vitamin A, niacin, vitamin B_6, and vitamin B_{12}.

Dietary Deficiencies

Evaluation of results of the analysis of these 2 vegan diets indicates that neither comprehensively met minimum contents in the AAFCO nutrient profiles for any life stage of cats. Although these diets were adequate in some nutrients, they contained less than the AAFCO minimum in others, namely overall protein content, specific amino acids, arachidonic acid, minerals, and vitamins. This is not surprising because many of these nutrients are limited in plant-based diets. Not all nutrients listed in the AAFCO nutrient profiles were included in the dietary analysis performed, so it is not known whether these other nutrients (eg, potassium, magnesium, iron, thiamin, or choline) would meet the AAFCO nutrient profiles minimum for adult maintenance or growth and reproduction of cats.

Protein content in diet B was less than the AAFCO minimum for adult maintenance as well as growth and reproduction. Diet A met the AAFCO minimum for protein (65 g/1,000 kcal). This is a practical minimum nutrient content for nonpurified foods formulated for cats and is not necessarily the absolute minimum content required when feeding purified diets of high digestibility. The **National Research Council (NRC)** nutrient requirements, on the other hand, establish minimum requirements of maximally bioavailable nutrients that will support a defined physiologic state.[12] Therefore, the AAFCO minimums do include a buffer of safety for diets composed of nonpurified, complex ingredients. As an example, the AAFCO minimum for adult cats is 65 g of protein/1,000 kcal, whereas the NRC minimal requirement is 40 g of protein/1,000 kcal (although the NRC recommended allowance is 50 g of protein/1,000 kcal).[11,12] However, ingredients with low bioavailability may not provide sufficient protein and

Table 2—Nutrient analysis of diet B, a commercial vegan diet formulated for cats that had a label claim that it met the nutritional values established by the AAFCO Cat Food Nutrient Profiles for all life stages (ie, adult maintenance as well as growth and reproduction), and the AAFCO nutrient profiles for growth and reproduction of cats.[11]

		AAFCO	
Nutrient	**Diet B**	**Minimum**	**Maximum**
Crude protein(g)	62	75	NA
Amino acids			
Arginine (g)	3.64	3.10	NA
Cystine (g)	0.62	NA	NA
Histidine (g)	1.15	0.78	NA
Isoleucine (g)	2.22	1.30	NA
Leucine (g)	3.73	3.10	NA
Lysine (g)	2.93	3.00	NA
Methionine (g)	0.80	1.55	3.75
Methionine plus cystine (g)	1.42	2.75	NA
Phenylalanine (g)	2.66	1.05	NA
Phenylalanine plus tyrosine (g)	4.35	2.20	NA
Taurine (g)	< 0.09*	0.25 and 0.50†	NA
Threonine (g)	2.04	1.83	NA
Tryptophan (g)	0.71	0.63	NA
Tyrosine (g)	1.69	NA	NA
Valine (g)	2.49	1.55	NA
Crude fat (g)	37.5	22.5	NA
Linoleic acid (g)	9.10	1.25	NA
Arachidonic acid (g)	< 0.04*	0.05	NA
Minerals			
Calcium (g)	0.1	2.5	NA
Phosphorus (g)	0.69	2.0	NA
Selenium (mg)	0.12	0.03	NA
Vitamin A (U)	< 391*	2,250	187,500
Niacin (mg)	10	15	NA
Pyridoxine (mg)	0.7	1.0	NA
Vitamin B_{12} (mg)	0.004	0.005	NA

Values reported are per 1,000 kcal.
See Table 1 for key.

amino acids to meet a cat's minimum requirements. Determining whether a cat's protein needs are truly being met by the protein content in diet A would require an assessment of the quality of the protein as well, which was beyond the scope of the analysis. Therefore, although diet B was below the AAFCO minimum for protein content, diet A also may have had an insufficient amount of protein to meet a cat's requirement. Although meeting the AAFCO minimum for a particular nutrient is one way to establish nutritional adequacy, the alternative and preferred method is to conduct a feeding trial in accordance with AAFCO feeding protocols. A feeding protocol helps to establish whether the nutrient amounts actually available to a cat are adequate to support health.

The 2 vegan diets tested were also low in content for a number of amino acids. Because taurine is abundant in animal sources but not in plants, vegetarian diets require supplementation with taurine. This is not to say that the need for supplementation is unique to vegan diets because many meat-based diets are also supplemented to achieve AAFCO minimum amounts. Both of the diets analyzed here were supplemented with taurine, yet the analysis revealed that both diets contained less than the AAFCO minimum. The low taurine content found in both of these diets may have far-reaching implications because of taurine's importance in the function of multiple organ systems. Syndromes that result from taurine deficiency include central retinal degeneration, dilated cardiomyopathy, poor growth, and reproductive failure as well as nervous and immune system dysfunction.[2-5,8,10,13]

Arginine, lysine, and methionine contents were also less than the AAFCO minimums in 1 or both of the diets. When a plant-based diet is fed, methionine supplementation is necessary because it is often a limiting amino acid and cats can neither synthesize nor conserve it.[2,4,10] Methionine was supplemented by the manufacturer in each of the diets but was still low in both. Although cystine can replace a large portion of methionine in a diet, the combination of methionine plues cystine content still was low in both diets (Tables 1 and 2). Signs of methionine deficiency include poor growth and dermatitis.[2,10] Lysine is generally limiting only in diets consisting mainly of grain. Diet A consisted largely of wheat flour; thus, the finding of inadequate amounts of lysine in diet A was consistent with the diet composition.

Although both diets had label claims of supplementation with arachidonic acid, both diets contained less than the AAFCO minimum for arachidonic acid. Diet A included a species of seaweed, *Ascophyllum nodosum*, as a source of arachidonic acid, whereas diet B listed both sea kelp and arachidonic acid. The low amounts detected in the analysis could have been attributable to uncontrollable variations in arachidonic acid concentration among batches of seaweed. Light,

temperature, and plant age may all affect nutrient availability in seaweeds, similar to the situation in other crops. In addition, storage of arachidonic acid can affect its activity. Signs of essential fatty acid deficiency include poor coat and growth, immune suppression, reduced efficiency of feed conversion, and problems with platelet aggregation.[10]

Only 3 minerals were analyzed in the analysis reported here. Diet B contained less than the AAFCO minimum for both calcium and phosphorus content. Furthermore, the calcium-to-phosphorus ratio was 0.2:1, compared with an ideal of 1:1 to 2:1. A low calcium content and low calcium-to-phosphorus ratio place cats at risk for nutritional secondary hyperparathyroidism.

Although the selenium content in diet A was greater than the AAFCO minimum, it was 62 times that minimum. A maximum amount of selenium has not been established by AAFCO or the NRC, but diet A may have provided more selenium than is optimal for long-term feeding in cats. The source of the excess selenium may have been the seaweed used to provide arachidonic acid.

Vitamin concentrations in the 2 diets also were of concern. Diet B contained less than the AAFCO minimum for vitamin A, whereas the vitamin A content of diet A was near the AAFCO maximum. Blindness, secondary infections, and dermatologic lesions have all been described[2,10] in association with vitamin A deficiency, whereas vitamin A toxicosis can result in cervical spondylosis, gingivitis, and tooth loss. Diet B also contained less than the AAFCO minimum amounts of niacin and vitamin B_{12}, whereas vitamin B_6 content was low in both diets. Cats require a relatively high amount of dietary vitamin B_6 because it forms a cofactor of aminotransferases, and cats use large amounts of aminotransferases as they metabolize protein. Low niacin and cobalamin contents, such as those found in diet B, also can result in clinical deficiencies. Niacin deficiency can cause weight loss, weakness, anorexia, oral ulcers, and diarrhea.[2,10] Poor appetite and growth, anemia, and neuropathies have been described in animals with cobalamin deficiency.[2,10]

We cannot definitively state the reason that our findings are not consistent with the nutritional claims made by the diet manufacturers. The methods used by the diet manufacturers to calculate the nutritional content of their diets were not revealed to us. Because there was no mention on the label that the manufacturers had performed a laboratory analysis, the reported values may have been derived from a calculation of expected nutritional content based on the ingredient list. The low amounts of nutrients that our laboratory analysis revealed underscore the importance of ensuring that a diet has undergone both laboratory analysis and feeding trials before it is used as the sole source of nutrition in cats.

Another potential reason for differences in reported nutritional composition could have been the analytic methods used. We expect our results to be reproducible because they were obtained from a reputable commercial laboratory whose personnel are experienced in this type of analysis; however, there is always the possibility for analytic error. Some nutrient analyses can have large analytic variations, depending on the method of analysis used (eg, up to 20% for lysine).[9] We submitted only a single sample of each diet to the laboratory. However, personnel at the commercial laboratory take measures to minimize variance in their results by concurrently assaying multiple samples of each submitted diet. Analysis of multiple cans of the canned food (ie, from various lots or batches) or multiple samples of the prepared diet may be helpful in determining the batch-to-batch variability of vegan diets. Because both diets had multiple nutrients that were in amounts less than the AAFCO minimums and many of these findings were similar between the 2 diets, it adds strength to the conclusion that the diets, if representative, are truly low in these nutrients. Finally, as alluded to previously for diet A, inconsistent nutrient content among ingredients used in diet composition (eg, seaweed) could also have contributed to differences in nutrient content of the entire diet. Further analyses are warranted to increase the statistical power as well as assess the reproducibility of our findings, which is the true test of validity in any scientific endeavor.

Conclusions

The 2 vegan diets analyzed and described here did not meet the minimum nutrient amounts cited in the AAFCO Cat Food Nutrient Profiles and thus cannot be recommended as a sole source of nutrition for cats. The premise of the food manufacturers that their vegan diets can meet 100% of a cat's nutritional needs was not supported by an independent dietary analysis. Despite obvious differences, all parties interested in this issue are united by a common concern for the welfare of cats. Thus, veterinarians have an important role to play in helping cat owners to understand the unique nutritional requirements of cats so that a diet can be chosen on the basis of the most complete information possible.

[a]Kienzle E, Engelhard R. A field study on the nutrition of vegetarian dogs and cats in Europe (abstr). *Compend Contin Educ Pract Vet Suppl* 2001;23:81.

[b]Vegecat KibbleMix, Harbingers of a New Age, Troy, Mont.

[c]Evolution diet vegan gourmet vegetable stew entrée, Evolution Diet, Saint Paul, Minn.

[d]Eurofins Woodson-Tenent Laboratories Division, Memphis, Tenn.

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