Analysis of thiamine concentrations in commercial canned foods formulated for cats

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Objective—To measure thiamine concentrations in commercial canned foods formulated for cats as an initial assessment of the variation among canned foods and to determine the effects of flavor (fish vs nonfish) of the food, texture (paté vs nonpaté) of the food, country of manufacture, and size of the company on thiamine concentration.

Design—Prospective cross-sectional study.

Sample—90 canned, nontherapeutic diets formulated for cats (1 fish and 1 nonfish flavor for each of 45 brands).

Procedures—Each canned food was homogenized, and thiamine concentration was analyzed with a fluorometric method.

Results—Thiamine concentration was below the minimums of the Association of American Feed Control Officials in 12 of 90 (13.3%) foods and below the recommended allowance of the National Research Council in 14 of 90 (15.6%) foods. Paté foods had significantly lower thiamine concentrations than did nonpaté foods, and foods from smaller companies had significantly lower thiamine concentrations, compared with concentrations in foods from larger companies. Flavor of food and country of manufacture were not significantly associated with thiamine concentration.

Conclusions and Clinical Relevance—A wide range of thiamine concentrations was found in the foods evaluated. Thiamine concentration in a substantial percentage of commercially available canned foods was below the amount recommended for adult cats. Additional research on interlot and intralot variation in thiamine concentrations of foods formulated for cats is warranted. Companies should implement strict quality control and analysis practices regarding food products. Clinicians should consider thiamine deficiency as a differential diagnosis in a cat with acute neurologic dysfunction. (J Am Vet Med Assoc 2014;244:175–179)

During the past 5 years, there have been 5 FDA-reported voluntary recalls involving thiamine-deficient pet foods in the United States, which ultimately involved 9 brands of foods formulated for cats and at least 23 clinically affected cats.1 This means that during the past 5 years, thiamine has been the primary reason for a vitamin-related recall in commercial foods formulated for cats. Clinical manifestations of this vitamin deficiency are variable and may range from mild gastrointestinal signs such as anorexia and vomiting to fulminant neurologic signs such as seizures and blindness.3,1 If left untreated, thiamine deficiency can result in death, whereas treatment may resolve all or most of the clinical signs.3 Thiamine deficiency is likely underreported because clinical signs are often nonspecific and biochemical analysis yields a lack of specific clinicopathologic changes. Many of the cases of thiamine deficiency reported to the US FDA as well as most of the cases in the literature involved cats that ate a diet consisting primarily of a commercially available canned food, although several of the recent recalls were of thiamine-deficient commercial dry foods formulated for cats.3,5 Despite the number of recalls in recent years, the prevalence of inadequate amounts of thiamine in commercial cat foods is unknown. However, it appears that there are an increasing number of companies and varieties of cat food with various levels of quality control; therefore, the prevalence of low thiamine concentrations in commercial canned foods has serious medical implications for cats.

Thiamine deficiency is likely an underdiagnosed and underreported vitamin deficiency of companion animals. Thiamine is a labile vitamin that is susceptible to inactivation or losses attributable to heat, pH, storage conditions, and naturally occurring thiaminases in certain ingredients. The increasing number of commercial canned foods currently available to cat owners and the variability of quality control measures among companies require that these commercial canned foods be evaluated to determine the number of thiamine-deficient products and the factors that affect thiamine concentrations. Therefore, the objectives of the study reported here were to determine the thiamine concentration in commercial canned foods formulated for cats as an initial assessment of the variation among canned foods and to determine the effects of flavor (fish vs nonfish) of the food, texture (paté vs nonpaté) of the food, country of manufacture, and size of the company on thiamine concentration.

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canned foods formulated for cats and to evaluate the association of brand, ingredients, and formulation of canned food with thiamine concentration.

**Materials and Methods**

**Sample**—Cans of randomly selected nontherapeutic commercial canned foods formulated for cats were purchased during a 1-week period in December 2012 through January 2013 from local grocery stores, mass merchandisers, and pet supply stores. Foods sold in pouches and trays were excluded. Only foods that were formulated to meet AAFCO nutrient profiles for adult feline maintenance or for all life stages of cats or that had been evaluated via feeding trials (in accordance with AAFCO procedures) for adult feline maintenance or all life stages of cats were eligible for inclusion in the study.7 Expiration dates for each can were recorded, and only cans that had at least 1 year until the labeled expiration date were included in the study.

**Procedures**—Flavors were selected with a random-number table. Two flavors (1 fish flavor and 1 nonfish flavor) determined by the labeled name of the food were randomly selected for each brand to address the question of whether a food with a large percentage of fish ingredients would be more likely to have low thiamine concentrations. Fish flavors needed to contain at least 1 fish or shellfish ingredient among the first 3 listed ingredients on the label, whereas nonfish flavors were defined as not having a fish or shellfish ingredient among the first 5 ingredients listed on the label. The total number of available diet flavors (ie, fish and nonfish) of each brand at each location was counted, and this total number was entered into a random-number generator. The number generated for fish flavor within each brand was used to identify the 1 fish flavor of that brand (on the basis of shell location) that would be selected for the study. A similar process was repeated for the nonfish flavor.

Texture of the food (paté vs nonpaté) was determined by use of the label information or from the company when the information was not present on the label; this was used to test the hypothesis of whether the texture of the canned food was related to the thiamine concentration. For companies that were not able to provide the texture of the diet, an additional can of the diet was purchased and opened by one of the authors (JEM), who determined whether the diet was a paté or nonpaté texture. Pate represented any type of ground food, and nonpaté included diets categorized as chunks, shredded, chopped, minced, or flaked.

The country of manufacture and whether each diet met AAFCO nutrient profiles on the basis of the formulation or had been tested by use of feeding trials were also obtained from the label. This information was used to compare thiamine concentrations among foods made in different countries and between testing methods (formulation vs feeding trial).

**Thiamine analysis**—The label was removed from each can, and each can was then assigned a letter and number designation. The unopened cans were shipped as 1 shipment to a commercial laboratory for analysis of the thiamine concentration.7 The method used for analysis measured thiamine monochloride (also known as free thiamine) and would therefore have measured both naturally occurring and supplemental forms of thiamine. After the cans arrived at the laboratory, they were opened and the entire contents of each can were homogenized. A sample (10 g) was then obtained from each homogenized product and used for thiamine analysis.

Thiamine concentrations were reported as a percentage on an as-fed basis. These data were converted to the number of milligrams per kilogram of dry matter by use of data on mean moisture concentration provided by the company. Three companies did not provide a mean moisture value but instead provided a range for the moisture content. For those canned foods, the mean moisture value for the range was used. Despite repeated attempts to obtain the information, 9 companies did not provide the moisture content of the product. For those canned foods, the maximum moisture percentage listed in the guaranteed analysis was used.

**Statistical analysis**—Data were examined graphically and with Kolmogorov-Smirnov tests. Because most data were not normally distributed, all data were reported as the median and range. Thiamine concentrations of commercial canned foods were compared between companies (large vs small), flavors (fish vs nonfish), and textures (paté vs nonpaté); comparisons were made by use of the Mann-Whitney U test. Companies were categorized as large (annual global retail sales, > $2 billion) or small (annual global retail sales, < $1 billion) on the basis of published annual global retail sales in 2010.5 This classification of company by size was performed to enable us to test the hypothesis that small companies would be more likely to produce canned foods with low thiamine concentrations. Thiamine concentrations were also compared with the AAFCO nutrient profiles for all life stages of cats (5.0 mg of thiamine/kg of dry matter) and the NRC RA for adult feline maintenance (5.6 mg of thiamine/kg of dry matter) to determine the number of diets with thiamine concentrations below these values. The number of diets with thiamine concentrations below the NRC RA was compared between groups (eg, fish vs nonfish) by use of a χ² analysis.

Data were analyzed with commercial statistical software. For all analyses, values of P < 0.05 were considered significant.

**Results**

Ninety cans representing 43 brands of cat food were included. Texture was classified as paté for 52 foods and nonpaté for 38 foods, and there were 45 foods in each of the fish and nonfish categories. Commercial canned foods were obtained from 12 stores, including 6 pet supply stores, 4 grocery stores, and 2 mass merchandisers. Companies were designated as large (n = 18 canned foods) or small (72). Country of manufacture for all diets evaluated was the United States (n = 63 canned foods), Thailand (20), New Zealand (4), and Canada (3). On the basis of information on the labels, 14 foods had been evaluated via AAFCO feeding trials and 76 foods were formulated to meet AAFCO nutrient profiles for adult feline maintenance or for all life stages of cats.
Median thiamine concentration of all canned foods (on a dry-matter basis) was 20.43 mg/kg of diet (9.29 mg/lb of diet; range, 0.45 to 352.00 mg/kg of diet [0.20 to 160.00 mg/lb] of diet). Thiamine concentration in 12 of 90 (13.3%) canned foods was below the AAFCO profiles on the basis of the minimum thiamine dry-matter content for all life stages of cats, and the thiamine concentration in 14 of 90 (15.6%) foods was below the NRC RA.

A significantly (P = 0.04) higher proportion of canned foods produced by small companies had thiamine concentrations below the AAFCO profiles and the thiamine concentration in 14 of 90 (15.6%) foods was below the NRC RA. A significantly (P = 0.04) higher proportion of canned foods produced by small companies had thiamine concentrations below the NRC RA (14/72), compared with the proportion for those produced by large companies (0/18). Median thiamine concentration in canned foods produced by small companies was 18.34 mg/kg of diet (8.34 mg/lb of diet; range, 0.45 to 300.50 mg/kg of diet [0.20 to 136.59 mg/lb of diet]), which differed significantly (P < 0.001) from the concentration in canned foods produced by large companies, for which the median was 138.25 mg/kg of diet (62.84 mg/lb of diet; range, 8.10 to 352.00 mg/kg of diet [3.68 to 160.00 mg/lb of diet]; Figure 1).

The proportion of canned foods in which the thiamine concentration was below the NRC RA was significantly (P = 0.02) higher for pate (12/52) than nonpaté (2/38) products. Median concentration of thiamine in the nonpaté foods was 32.74 mg/kg of diet (14.88 mg/lb of diet; range, 1.82 to 300.50 mg/kg of diet [0.83 to 136.59 mg/lb of diet]), which was significantly (P < 0.001) higher than that in the pate foods (median, 16.14 mg/kg of diet [7.34 mg/lb of diet]; range, 0.45 to 352.00 mg/kg of diet; Figure 2).

The proportion of canned foods in which the thiamine concentration was below the NRC RA did not differ significantly (P = 0.90) between foods manufactured in the United States (10/63) and those manufactured in other countries (4/27). Additionally, there was no significant (P = 0.74) difference in median thiamine concentration between canned foods manufactured in the United States (median, 20.40 mg/kg of diet [9.27 mg/lb of diet]; range, 0.45 to 352.00 mg/kg of diet) and canned foods manufactured in other countries (median, 21.50 mg/kg of diet [9.77 mg/lb of diet]; range, 1.50 to 300.50 mg/kg of diet [0.68 to 136.59 mg/lb of diet]).

The proportion of canned foods in which the thiamine concentration was below the NRC RA in the fish category (9/45) did not differ significantly (P = 0.25) from the proportion for the nonfish category (5/43). Median thiamine concentration in canned foods in the fish category was 20.31 mg/kg of diet (9.23 mg/lb of diet; range, 0.45 to 300.50 mg/kg of diet), which did not differ significantly (P = 0.64) from the thiamine concentration in canned foods in the nonfish category (median, 20.45 mg/kg of diet [9.30 mg/lb of diet]; range, 1.33 to 352.00 mg/kg of diet [0.60 to 160.00 mg/lb of diet]). There was no significant (P = 0.51) difference between the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated to meet the AAFCO nutrient profiles (11/76) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14) and the proportion of canned foods with a thiamine concentration below the NRC RA that were formulated via AAFCO feeding trials (3/14).
range, 0.45 to 298.60 mg/kg of diet (0.20 to 135.73 mg/lb of diet) was not significantly (P = 0.76) different from the median concentration in canned foods formulated to meet AAFCO nutrient profiles for cats (20.43 mg/kg of diet).

Discussion

The study reported here revealed a wide variation in thiamine content of commercial canned foods formulated for cats and a substantial number of foods in which the thiamine concentration was below the AAFCO minimums and below the NRC RA. Although flavor (fish vs nonfish) and country of manufacture did not appear to influence thiamine content, the texture of the food played a role in the thiamine concentration of the canned food. Pâté foods were more likely to be associated with lower thiamine concentrations than were nonpâté foods and had a greater proportion of foods with a thiamine concentration below the NRC RA. Production of canned food is a multistep process that involves grinding and mixing the food, filling the cans, sealing the cans, and sterilizing food within the cans. The sterilization (retort) step is important for destroying common pathogenic bacteria. The retort process for commercial canned foods formulated for cats involves heating the entire food product within a sealed can for a specified period at a specific temperature. Heat is transmitted from the outside of the can toward the center of the can. All 90 commercial canned foods in the present study contained supplemental thiamine (in the form of thiamine mononitrate) in the ingredient list; however, the percentage of naturally occurring thiamine from ingredients versus supplemental thiamine in the total thiamine content cannot be determined from this study. Regardless, thiamine is a heat-labile vitamin, and thiamine losses of 50% to 90% as a result of processing have been described. Commercially produced cans of pâté foods are homogenous with regard to moisture and texture and may more consistently transfer heat during processing, compared with heat transfer for nonpâté foods. More consistent heat transfer may lead to more loss of thiamine during a similar processing period, although testing this hypothesis would require additional studies. In addition, many canned diets contain alkalizing gelling agents that alter the pH and therefore the availability of thiamine in the diet. A variety of manufacturing techniques currently used to provide foods of various textures (eg, gel, pâté, minced, or chunks) could also influence thiamine content of commercial cat foods. The authors are not aware of any publications on the effects of these manufacturing techniques on thiamine content. Responsible companies take these issues into consideration: they use analytic methods to estimate the amount of thiamine lost to processing or inactivation because of the pH, and they add supplemental thiamine to the product prior to the retort step to compensate for impending losses.

Specific ingredients of a food may also affect the amount of thiamine in the finished product. Thiamine is found naturally in many plants, particularly whole grains (eg, wheat germ and rice) and legumes, as well as in yeast. Thiamine is also found in meat products, and it is concentrated in organ meats such as the liver, heart, and kidneys. Some ingredients, namely the viscer of certain species of fish and some shellfish, contain thiaminases, which can cause additional thiamine losses. Thiaminases are naturally occurring enzymes that degrade thiamine in a time- and concentration-dependent manner. Therefore, diets high in fish ingredients theoretically could be considered more likely to be thiamine deficient than those consisting primarily of other protein sources such as chicken or beef. On the other hand, it appears that supplemental thiamine is routinely added to commercial foods formulated for cats, so ingredients may not play an important role.

Investigators in a study in 1970 analyzed 11 samples of multiple flavors of 5 brands of cat food and found that most of the samples had low thiamine concentrations. However, there were a number of limitations to that study, including lack of randomization of samples and the failure to clearly define flavors and ingredients. In the present study, the flavor of the cat foods (ie, fish vs nonfish), as determined by the ingredient list, was not associated with thiamine concentration. Whether this was because companies anticipated the possibility of thiaminases and supplemented the food to compensate for this possibility or because fish ingredients are truly not associated with low thiamine concentrations in commercial canned foods could not be determined from the present study. Further evaluation of the effects of ingredients is needed to better understand their role in the risk of thiamine deficiency.

The size of the company that manufactured the cat food was significantly associated with thiamine content of the canned foods. Foods produced by large companies were less likely to have a thiamine concentration below the NRC RA. This finding may have been related to the quality control practices of each company. Companies that routinely test their ingredients and the finished products would be less likely to produce foods that contain nutrients at concentrations below the AAFCO minimums and NRC RA. However, such testing is expensive and does not appear to be routinely performed by all companies.

Thiamine is an extremely heat-labile vitamin, and vitamin content may differ among production lots of cat food or even within individual cans of the same lot. Variation of thiamine content within a particular flavor, brand, or texture of food was not assessed in the present study and should be evaluated. Pâté foods were associated with a significantly lower thiamine content than nonpâté foods; however, nonpâté foods were not further categorized as to the manufacturing technique (eg, shredded or chopped). It is possible that there are other specific textures that may be associated with a low thiamine content in commercial canned foods, and this should be investigated.

A limitation of the present study was its cross-sectional nature. There were many brands not eligible for inclusion in the study because of the ingredient list on the label or the available choices of flavors. Also, calculations of the thiamine content used moisture content provided by the company, rather than actual analysis of the moisture content of each food. Additionally, several types of moist foods (eg, those sold in pouches or plastic tubs) were not evaluated in this study. Therefore,
the true prevalence of commercial foods with thiamine concentrations below the AAFCO minimums and NRC RA may be higher or lower than that reported in this study.

Companies should strive to measure and limit thiamine loss in canned foods and to implement strict quality control practices. Clinicians should consider thiamine deficiency as a possible differential diagnosis in a cat with acute neurologic dysfunction, especially in conjunction with gastrointestinal signs. It is important to obtain a complete dietary history because it may help to identify potential risk factors for thiamine deficiency or other nutritional problems.

References