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Evaluation of recipes of home-prepared maintenance diets for dogs

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Despite the availability of complete and balanced commercial canine maintenance diets, many owners choose to prepare their pet's diet at home for reasons such as having more control of the foods that their pet eats, distrust in pet food companies, and the desire to feed a more natural diet.[1] Recipes published by veterinarians and lay writers are readily accessible to pet owners in the popular media (Internet, pet magazines, and books). However, current recommendations are that home-prepared diets are best evaluated and formulated by a veterinary nutritionist.[2] In general, many home-prepared diets are more costly, more time-consuming, and less convenient than are commercial diets, and many home-prepared diets have major nutritional imbalances.[3–7] Another concern is lack of clear instructions in many recipes, which necessitates assumptions or judgments by pet owners. The nutritional adequacy of recipes for 67 home-prepared diets for dogs and cats with chronic kidney disease has been evaluated,[6] and assumptions were needed for the preparation of every recipe. Lack of clear instructions likely increases variability and potentially impacts the nutritional profile of the prepared diet. Combined with problems of nutritional adequacy, this may result in substantial harm to pets when home-prepared diets are used on a long-term basis.

The information reported here is intended to provide an evaluation of recipes for home-prepared diets for adult dogs conducted via computer-based software and compared with recommendations for essential nutrient intake in adult dogs as provided by the NRC[8] and AAFCO.[9] A secondary objective was to compare recipes written by veterinarians with those written by nonveterinarians. We believed that most of the recipes would not meet requirements for essential nutrients and that recipes written by nonveterinarians would have a higher number of deficiencies than recipes written by veterinarians. We also expected all recipes to require that at least 1 assumption would be necessary for preparation of the diet and dietary analysis.

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Abbreviations

AAFCO	Association of American Feed Control Officials
DHA	Docosahexaenoic acid
EPA	Eicosapentaenoic acid
ME	Metabolizable energy
MR	Minimal requirement
NRC	National Research Council
RA	Recommended allowance

Furthermore, we compared the computer-based assessment with laboratory quantification of selected nutrients in a subset of the diets. We believed that the 2 methods of dietary assessment would yield similar findings with respect to the adequacy of essential nutrients.

Qualitative Dietary Assessment

Veterinary textbooks, pet care books for owners, and websites were searched for recipes of home-prepared canine maintenance diets. Recipes were included only if they had no explicit indication that they were intended for one of the following: use as a treat; feeding during growth, lactation, or gestation; supplemental or intermittent feeding; or treatment of a specific medical condition. Included recipes also provided sufficient information and details about the ingredients and preparation methods to enable analysis. Two hundred recipes were obtained from 34 sources (133 recipes were obtained from 2 veterinary textbooks and 9 pet care books for owners,[10–20] and 67 recipes were obtained from 23 websites[21–46]). Of these, 129 (64.5%) were written by veterinarians, whereas the remaining 71 (35.5%) were written by nonveterinarians.

Qualitative analysis of each recipe included an assessment of the specificity of ingredients and preparation instructions. In recipes that allowed substitutions or listed ranges, the mean value for ingredients was used (eg, a specification of 2 cups of mashed potatoes or rice was analyzed as 1 cup of mashed potatoes plus 1 cup of rice [for conversion to metric, 1 cup = 247 mL], and a specification of 1 to 2 eggs was analyzed as 1.5 eggs). When a recipe was not specific for supplement-type products (eg, a multiple vitamin-mineral tablet), products of national leading brands were used.[a–d] Whenever possible, common and widely available types and varieties of ingredients were used to satisfy vague instructions (eg, regular ground beef was analyzed as ground beef that contained 15% fat).

Most (184 [92%]) recipes contained vague or incomplete instructions that necessitated 1 or more assumptions for the ingredients, method of preparation, or supplement-type products. Supplement-type products were not included in 58 (29%) recipes. Most (169 [84.5%]) recipes did not provide specific feeding instructions; instead, some included general instructions to modify amounts on the basis of each individual pet's size and body weight (including any patterns of weight gain or loss). Similarly, most (171 [85.5%]) recipes did not provide calorie information or the target body weight for a pet. Additionally, some sources provided recipes that differed widely in calorie content for the same-size pet. Thirteen (6.5%) recipes included garlic or onion, which are foods associated with hemolytic anemia in dogs.[47,48]

Quantitative Assessment via Computer-based Analysis

Quantitative analysis was performed with diet formulation software[e] and both publicly available[f] and proprietary[g] nutrient analysis databases. Quantitative analysis included calculation of total energy; energy density; moisture content; proportion of calories contributed by protein, fat, and carbohydrate on an ME basis; and essential nutrient concentrations. Essential nutrient concentrations were assessed on an energy basis to account for differences in energy density of the diets; these nutrients were compared with the NRC RA and, when available, the MR for adult dogs at maintenance[8] and the minimum nutrient concentrations for adult dogs in the AAFCO dog food nutrient profile.[9] Linoleic acid and the combination of EPA plus DHA were the only fatty acids assessed. Physiologic fuel values (kcal/g of metabolized fat, protein, and carbohydrate) applied to recipe analyses were for specific human foods to reflect the expected higher digestibility of human foods than of commercial pet foods.[49] Iodine, chloride, and vitamin K content could not be assessed because of a paucity of analysis data for these nutrients in many of the ingredients.

Statistical analysis was performed, which included a Shapiro-Wilk test to confirm that data were not normally distributed. Descriptive statistics were calculated with computer-based software.[h] The number of nutrients not meeting NRC values for RA, MR, 75% of MR, and 50% of MR in each recipe were counted and compared between recipes written by veterinarians and nonveterinarians via the Wilcoxon-Mann-Whitney test via computer software.[i] Significance was set at a value of $P < 0.05$.

Quantitative analysis with computer-based assessment revealed that recipes had large variations in total energy (median, 1,455 kcal; range, 380 to 16,348 kcal), caloric density (median, 4,978 kcal/kg of dry matter; range, 2,759 to 6,043 kcal/kg of dry matter), moisture (median, 63.4%; range, 37.2% to 82.6%), and calorie distribution on an ME basis for protein (median, 27.2%; range, 13.3% to 69.2%), fat (median, 36.8%; range, 9.8% to 62.2%), and carbohydrate (median, 37.0%; range, 8.7% to 62.1%). There were also variations in the concentrations of crude protein, amino acids, minerals, vitamins, linoleic acid, and the combination of EPA plus DHA (**Table 1**).

Only 3 recipes provided all essential nutrients in concentrations meeting or exceeding the NRC RA, and another 2 recipes provided all essential nutrients in concentrations meeting or exceeding the NRC MR; all 5 of these recipes were written by veterinarians. Nine recipes provided all essential nutrients in concentrations exceeding the AAFCO nutrient profile minimums for adult dogs; 4 of these also met or exceeded the NRC RA or NRC MR. Of these 9 recipes, 8 were written by veterinarians. Overall, most (190/200 [95%]) recipes resulted in at least 1 essential nutrient at concentrations that did not meet NRC or AAFCO guidelines, and many (167 [83.5%]) recipes had multiple deficiencies. The most commonly deficient nutrients, when compared with the NRC MR or NRC RA, were zinc (138 [69%] recipes), choline (129 [64.5%] recipes), copper (108 [54%] recipes), the combination of EPA plus DHA (107 [53.5%] recipes), and calcium (70 [35%] recipes). Only crude protein, arginine, and pyridoxine were at concentrations exceeding the NRC RA in all recipes; histidine, leucine, valine, isoleucine, lysine, and total fat concentrations were too low in only 1 or 2 recipes. Only pyridoxine concentrations exceeded AAFCO guidelines in all recipes; histidine, leucine, valine, isoleucine, lysine, and total fat concentrations were too low in only 1 or 2 recipes. This likely was associated with an apparent focus on owner preferences and diet palatability over nutritional adequacy because many owners view meat as an integral component of the diet for dogs.

Vitamin D or vitamin E concentrations, or both, were not defined for some ingredients in the database, but source ingredients (primarily certain cuts of meat and vegetable oils) would be expected to provide these nutrients in the diet. Of the recipes for which complete nutrient information for these vitamins was available for all ingredients, 102 of 167 (61.1%) were too low in vitamin D and 79 of 175 (45.1%) were too low in vitamin E.

Some deficiencies were so severe that nutrient concentrations did not reach 50% of the NRC RA; these included diets deficient in vitamin D (97/102 [95.1%]), zinc (76/138 [55.1%]), choline (56/129 [43.4%]), and vitamin E (31/79 [39.2%]). Nine recipes surpassed the safe upper limit for vitamin D, and 6 surpassed the safe upper limit for the combination of EPA plus DHA.

Deficiencies in these recipes may translate to adverse clinical effects when fed on a long-term basis. For example, diets deficient in choline can cause weight loss and fat accumulation in the liver,[8] and vitamin D deficiency may cause substantial musculoskeletal abnormalities, particularly in growing puppies.[8] For some nutrients (eg, zinc and vitamin E), clinical signs of deficiency may appear only after a prolonged period of feeding a deficient maintenance diet.[8] Severity and temporality of clinical signs associated with inadequate nutrient intake may also vary with the degree of deficiency, and many recipes analyzed provided less than half of the NRC RA for several nutrients.[8]

Three recipe groups (each consisting of 7 recipes, all of which were from the same source) were assessed together to reflect feeding instructions, which recommended rotation of the recipes to compensate for nutritional deficiencies in each individual recipe.[18] Com-

Table 1—Median and range values for essential nutrients of recipes for home-prepared diets for adult dogs determined on the basis of computer analysis, compared with the NRC RA values, and the number of recipes that do not meet NRC RA values for each nutrient.

Variable	NRC RA (/1,000 kcal)	Median (/1,000 kcal)	Range (/1,000 kcal)	No. (%) below RA
Crude protein (g)	25.0	68.3	36.7–161.5	0 (0)
Total fat (g)	13.8	32.0	3.1–77.8	9 (4.5)
Amino acid (g)				
Arginine	0.88	4.48	0.9–10.6	0 (0)
Histidine	0.48	1.99	0.16–6.87	1 (0.5)
Isoleucine	0.95	3.18	0.57–7.89	2 (1.0)
Methionine and cystine	1.63	2.54	0.30–6.25	25 (12.5)
Leucine	1.70	5.28	0.53–13.65	2 (1.0)
Lysine	0.88	3.70	0.50–21.10	2 (1.0)
Phenylalanine and tyrosine	1.85	5.21	0.56–12.87	3 (1.5)
Threonine	1.08	2.85	0.34–7.25	8 (4.0)
Tryptophan	0.35	0.69	0.07–1.86	12 (6.0)
Valine	1.23	3.43	0.40–8.43	2 (1.0)
Mineral				
Calcium (g)	1.00	1.03	0.07–3.56	70 (35.0)
Phosphorus (g)	0.75	0.97	0.54–2.27	17 (8.5)
Magnesium (mg)	150	210	54–362	55 (27.5)
Sodium (mg)	200	434	8–3,110	15 (7.5
Potassium (g)	1.00	1.74	0.01–5.40	15 (7.5)
Iron (mg)	7.50	9.27	0.13–46.01	49 (24.5)
Copper (mg)	1.50	0.98	0.22–6.51	108 (54.0)
Zinc (mg)	15.00	9.59	0.12–81.70	138 (69.0)
Manganese (mg)	1.20	2.13	0.01–8.30	51 (26.0)
Selenium (µg)	87.5	97.0	20.0–243.0	69 (34.5)
Vitamin				
A (µg)	379.0	679.5	1.25–5,797.2	32 (16.0)
D (U)	339.0	41.2	0–1,697.7	102 (61.0)
E (mg)	7.50	3.36	0.32–91.60	79 (45.1)
Thiamin (mg)	0.56	0.91	0.15–5.05	29 (14.5)
Riboflavin (mg)	1.30	1.02	0.09–5.03	81 (40.5)
Pyridoxine (mg)	0.375	1.82	0.40–9.80	0 (0)
Niacin (mg)	4.25	22.70	1.06–77.35	5 (2.5)
Pantothenate (mg)	3.75	4.58	0.56–23.75	54 (27.0)
Cobalamin (µg)	8.75	8.90	0–92.00	68 (39.0)
Folate (µg)	67.5	239.4	0.9–1,905.4	9 (4.5)
Choline (mg)	425.0	255. 5	0–591.6	129 (64.5)
Fatty acid (g)				
Linoleic acid	2.8	3.7	0.5–21.1	60 (30.0)
EPA and DHA	0.11	0.05	0–2.83	107 (53.5)

The n for each variable is 200, except for vitamin D (n = 167) and vitamin E (175).

bined analysis of these 3 groups did not result in a complete diet because several nutrients were below the RA or MR, including zinc (3/3 groups), choline (2/3), vitamin D (2/3), vitamin B12 (1/3), and vitamin E (1/3).

Many proponents of less structured recipes for home-prepared diets assert that although each day's meal is not necessarily complete, rotation and variety will provide a balanced diet overall. Our analysis indicated that this assumption was unfounded because evaluation of 3 recipe groups, each of which comprised 7 separate recipes, did not eliminate deficiencies. In addition, many recipes had similar deficiencies, with 14 nutrients provided at inadequate concentrations in at least 50 recipes. Thus, even the use of a strategy for rotation among several recipes from multiple sources would be unlikely to provide a balanced diet.

A greater number of recipes written by nonveterinarians had deficiencies, those recipes had significantly ($P = 0.001$) more nutrients that were deficient, and the deficiencies were more severe, compared with results for recipes written by veterinarians (**Table 2**). The lower number of deficiencies per recipe in those written by veterinarians may have been associated with a better understanding of canine nutrition by veterinary professionals, although most of the veterinarian-written recipes had at least 1 nutrient deficiency. Only 4 recipes written by board-certified veterinary nutritionists were available for evaluation; all 4 had nutrient profiles that were within the AAFCO-recommended ranges for an adult canine maintenance diet.

Quantitative Assessment via Laboratory Analysis

Computer-based diet analysis relies on nutrient databases for foods; several hundred databases are maintained by government agencies in several countries and by research institutions and other organizations. Nutrient values for foods are not always established via analytic methods despite the need for reasonable accuracy. The USDA National Nutrient Database for Standard Reference uses quality control procedures to validate the accuracy of their database. Specific nutrient values sometimes are established with computerized algorithms via estimation and extrapolation, rather than via analytic methods involving the food itself.[50,51] Furthermore, although the USDA database provides valuable and useful information regarding nutritional profiles for many food items, missing or partial information may hinder complete nutritional analysis or diet formulation.

Reports of comparisons between data obtained through computer-based evaluation of diets and data obtained via laboratory analysis are limited. To our knowledge, no veterinary studies have been reported in which such comparisons were performed.

For laboratory analysis of nutrient content, 15 recipes were selected and prepared in accordance with the provided directions. Recipes were selected to represent various sources (between 1 and 3 recipes from each of 5 books and 4 websites) and a variety of ingredients; selected recipes included only those that involved ingredients with defined database values for analyzed nutrients. Ingredients were purchased at a local grocery store, and diets were prepared in a typical domestic kitchen with common kitchen appliances. When tablets were included in diets, they were ground with a mortar and pestle; after the ground tablets were added to the diets, the diets were pureed in a kitchen blender to ensure homogeneity. Samples were shipped on ice to laboratory facilities for determination of energy density[j] (via a bomb calorimeter), proximate analysis[j] (ash, moisture, crude fat, and crude protein content), and selected essential nutrient concentrations. Because of cost constraints, analysis of only select limiting nutrients was possible. These nutrients included vitamin D, vitamin E, calcium, copper, iron, magnesium, manganese, phosphorus, potassium, selenium, sodium, and zinc.[j,k]

Energy density calculated with specific physiologic fuel values for each recipe[49] or with a bomb calorimeter[j] was determined for the 15 diets. Density values determined with the bomb calorimeter (median, 142 kcal/100 g of diet; range, 83 to 240 kcal/100 g of diet) were 10% to 15% higher than the values calculated on the basis of physiologic fuel values (median, 124 kcal/100 g of diet; range, 84 to 157 kcal/100 g of diet); physiologic fuel values accounted for digestibility of protein, fat, and carbohydrate. Bomb calorimetric measurement provides information regarding the energy released as a result of combustion of an organic compound and therefore is expected to yield higher values than the amount of energy obtained through metabolism of the same food.

Selected nutrient concentrations obtained via laboratory measurement were compared with values obtained via computer analysis and with NRC RA values (**Table 3**). Differences in nutrient concentrations between values determined via laboratory measurement and computer analysis ranged between 0.21% and 62.10% (**Figure 1**). Computer analysis was highly predictive of deficiencies or excesses of nutrients as measured via laboratory methods. There were only 4 discrepancies: total fat concentration in one of the recipes was too low as assessed with the computer analysis but was above the NRC RA as determined via the laboratory analysis, and copper concentrations in 2 recipes and choline concentration in 1 recipe exceeded the NRC RA as assessed with the computer analysis but were too low as determined via the laboratory analysis.

Similar to our results for canine diets, there is generally good agreement between laboratory analysis and computer databases for meals formulated for humans. Investigators in 1 study[52] compared chemical analysis of 13 nutrients in 36 meals with values for 4 nutrient databases and found small (10%) but significant differences for concentrations of saturated, monounsaturated, and polyunsaturated fatty acids, potassium, and magnesium and larger differences (differences of 15% to 20%) for iron concentrations. In an-

Table 2—Median (range) number of nutrients in each recipe of home-prepared diets for adult dogs (determined on the basis of computer analysis) that did not meet values for NRC RA, MR, 75% of MR, and 50% of MR.

Variable	Written by veterinarians (n = 129)	Written by nonveterinarians (n = 71)	*P* value*
No. of nutrients less than NRC RA	5 (0–16)	7 (1–13)	0.001
No. of nutrients less than NRC MR	4 (0–13)	6 (1–11)	< 0.001
No. of nutrients < 75% of NRC MR	3 (0–12)	4 (0–10)	0.010
No. of nutrients < 50% of NRC MR	2 (0–9)	0 (0–6)	0.841

*Significance was set at a value of $P < 0.05$.

Table 3—Selected nutrient concentrations obtained via computer analysis and via laboratory measurement of 15 recipes for home-prepared diets for adult dogs.

Variable	NRC RA‡	Computer analysis*		Laboratory measurement†	
		Median	Range	Median	Range
Crude protein (g)	25.00	60.48	43.16–109.61	58.00	44.44–93.0
Total fat (g)	13.80	35.83	11.88–68.30	31.31	16.82–67.98
Vitamin D (U)§	339	252.00	8.73–1,346.36	285.48	13.08–1,371.00
Vitamin E (mg)	7.50	23.56	1.74–60.93	23.68	2.99–72.1
Choline (mg)	425	279.18	128.79–906.39	259.70	132.54–907.89
Zinc (mg)	15	12.85	4.26–58.42	14.30	4.39–93.00
Copper (mg)	1.5	1.92	0.60–5.45	2.32	0.67–5.04

Values reported are /1,000 kcal.

*Based on total energy of the diet determined by use of specific physiologic fuel values applied to calculated amounts of protein, fat, and carbohydrate for each ingredient.[49] †Based on total energy of the diet determined by use of Atwater energy factors applied to measured amounts of protein, fat, and carbohydrate for each diet. ‡Information obtained from NRC.[8] §The NRC safe upper limit is 800 U/1,000 kcal[8]; this value was exceeded by 3 recipes.

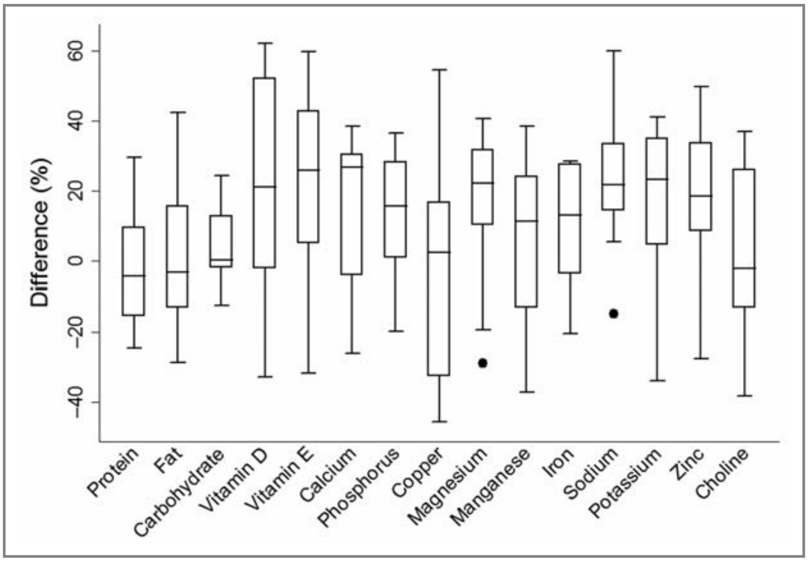

Figure 1—Box-and-whisker plots of the percentage difference between nutrient concentrations obtained via laboratory analysis on an energy basis and values obtained via computer analysis for recipes of home-prepared diets for adult dogs. The boxes represent the interquartile range (25th to 75th percentiles) of the data; the horizontal line within each box represents the 50th percentile (median); the bars above and below the boxes represent the highest and lowest data points, respectively, within 1.5 times the interquartile range; and the circles represent individual data points > 1.5 times the interquartile range.

other study[53] in which investigators evaluated the reported daily intakes of 9 minerals by humans, differences of up to 11% were found between values obtained via laboratory analysis and those reported in the USDA database.

The few discrepancies we detected may have simply reflected a lack of homogeneity of the submitted samples. However, other potential reasons include variation in preparation methods used by the authors and those used by USDA personnel when establishing nutrient values for their database (eg, the amount of fat drained and discarded during preparation of ground meat). Another factor is the difference in the method of calculating energy provided by the recipes. The recipe analysis software we used calculated ME values by use of specific Atwater values assigned by the USDA to various ingredients (eg, 8.79 kcal/g of dairy fat vs 9.02 kcal/g of beef fat). In contrast, the laboratory values were calculated with general Atwater values applied to all foods (ie, 4 kcal/g of protein or carbohydrate and 9 kcal/g of fat). These differences likely influenced the discrepancies in nutrient concentrations because the values were calculated and compared on an energy basis. Finally, discrepancies between label nutrient concentration and analyzed values in supplement-type products may have also accounted for some differences in these nutrient profiles.[54] Most differences we detected between computer-based and laboratory values were < 20%; those > 40% were mostly attributable to higher values for the laboratory analysis. We assumed that there were actual discrepancies between values determined via computer analysis and laboratory measurements for many recipes, which indicates the challenges in formulation of a home-prepared diet when relying on database accuracy and computer-based calculations.

Clinical Summary

To our knowledge, the information reported here represents the largest number of home-prepared recipes that have been evaluated for nutritional adequacy in dogs and is the first report of the comparison between computer-based assessment and laboratory quantification of selected nutrients. This information further defines potential problems with home-prepared recipes that are readily available to pet owners. Few recipes that we evaluated provided all of the essential nutrients in concentrations meeting or exceeding the NRC MR or RA or the AAFCO dog food nutrient profiles for canine maintenance diets. Computer-based analysis was highly predictive of deficiencies or excesses of nutrients as measured via laboratory methods, which supports the reliability of computer-based analysis for use in detecting inadequacies in recipes; however, discrepancies were found, and absolute values of specific nutrient concentrations differed by up to 62.1%. Because complete laboratory analysis of home-prepared diets is costly and not practical in most circumstances, recipes for home-prepared diets should include a safety margin for each nutrient to account for variations in ingredient nutrient profiles, digestibility, bioavailability, and other uncontrolled factors that may influence the final composition of a diet. Formulation of recipes for home-prepared diets requires expert input to minimize the risk of problems, and we recommend that recipes for home-prepared diets for dogs be obtained from or evaluated by board-certified veterinary nutritionists or veterinarians with advanced training in nutrition who are experienced and able to understand and address these concerns.

a. Centrum Adults Under 50, Pfizer Inc, New York, NY.
b. Flintstones Chewables Complete, Bayer Healthcare LLC, Morristown, NJ.
c. Pet-Tabs, Virbac Animal Health Inc, Fort Worth, Tex.
d. Solgar Bone Meal Powder, Solgar Inc, Leonia, NJ.
e. Balance IT Autobalancer, Davis Veterinary Medical Consulting Inc, Davis, Calif.
f. USDA, Agricultural Research Service, USDA National Nutrient Database for Standard Reference, Release 24. 2011.
g. Davis Veterinary Medical Consulting Inc, Davis, Calif.
h. Microsoft Office Excel 2007, Microsoft Corp, Redmond, Wash.
i. StatXact 9.0, Cytel Software Corp, Cambridge, Mass.
j. Nutrition Analysis Center, Eurofins Scientific Inc, Des Moines, Iowa.
k. California Animal Health & Food Safety Laboratory System, University of California-Davis, Davis, Calif.

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