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Nutritional evaluation of new alternative types of dog foods including raw and cooked homemade-style diets

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ABSTRACT

Background: New alternative types of pet foods such as raw and cooked homemade-style diets containing human food ingredients have been introduced due to a trend of pet humanization and diversification of consumer needs.
Objectives: To evaluate nutritional adequacy of new alternative types of dog foods containing human food ingredients as maintenance diets for dogs.
Methods: Eleven homemade-style foods for adult dogs were purchased from online channel in Korea and analyzed to evaluate nutritional adequacy for adult dogs. Nutrients analyzed included crude protein, amino acids, crude fat, fatty acids, and minerals.
Results: Crude protein and amino acids in all products satisfied Association of American Feed Control Officials (AAFCO) requirements. Crude fat in one of 11 products did not meet AAFCO requirements. The most deficient minerals were selenium (10 of 11, 90.9%), copper (five of 11, 45.5%), zinc (five of 11, 45.5%), potassium (three of 11, 27.3%), calcium (three of 11, 27.3%), iron (two of 11, 18.2%), and magnesium (one of 11, 9.1%). Six products were not in the range of the recommended Ca:P ratio in AAFCO dog food maintenance nutrient profiles.
Conclusions: This study performed nutritional evaluation of raw and cooked homemade-style foods as maintenance diets for adult dogs. Some nutritional inadequacies were observed including some minerals, Ca:P ratio, and omega-6:omega-3 fatty acid ratio, although three products (26.2%) satisfied the AAFCO standard except selenium. Overall, the data suggest a need for accurate nutritional adequacy statement for consumers based on proper methods to validate the formula.

Keywords: Alternative dog diets; nutrition; nutritional analysis; pet food; human-grade dog diets

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Conflict of Interest
The authors declare no conflicts of interest.

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INTRODUCTION

The global pet food market was $93.94 billion in 2020 according to Fortune Business Insights [1]. The Korean pet food market reached USD 1192.46 million in 2021. It is expected to grow at a compound annual growth rate of 9.4% between 2023 and 2028 [2]. Pet foods are conventionally classified into dry foods (water content: 10%–12%) and wet foods (water content: 65% or more). Pet foods can also be divided into "complete" and "complementary" according to the nutritional adequacy. "Complete," namely maintenance pet foods should contain all essential nutrients at levels that meet target animal's requirements according to the Association of American Feed Control Officials (AAFCO) [3]. In the United States, all pet food labels in packages have been required to contain nutritional adequacy statement except for some products such as treats, snacks and supplements since 1984. AAFCO regulations allow three basic methods to substantiate "complete and balanced" claims which are the formulation method, the feeding trial method, and the family method [4]. On the other hand, there are no regulations on nutritional adequacy in Republic of Korea [5]. Therefore, in most cases, there is no nutritional adequacy statement on the packaging, and even if there is, it is difficult to trust the statement written by the manufacturers. Nutritional adequacies of conventional pet foods have been studied in other countries [6-15], but not in Republic of Korea.

Recently, new alternative types of pet foods such as raw foods and cooked homemade-style diets are increasing besides conventional types of pet foods due to a trend of pet humanization and diversification of consumer needs [16-18]. The classification and definition of alternative diets including raw foods and cooked homemade-style diets are well noted in the study of Parr and Remillard [16]. Conversely, concerns about alternative diets including raw foods and cooked homemade-style diets are also increasing, such as nutritional imbalances and long-term feeding as maintenance diets [19-21]. However, studies performing nutritional evaluation for these types of pet foods have been rarely reported. To the best of our knowledge, there have been no published studies evaluating nutritional adequacy of new types of dog foods such as raw foods and cooked homemade-style diets as maintenance diets for dogs. Thus, the aim of this study was to analyze essential nutrients and nutritional adequacies of 11 new alternative types of dog foods as maintenance diets for adult dogs. Results of this study could contribute to dogs' health and provide the right guide for pet owners and pet food manufacturers.

MATERIALS AND METHODS

Sample collection

Eleven different raw and cooked homemade-style diets for adult dogs were purchased for analysis from online channel in Republic of Korea. Eight samples were locally manufactured, and three samples were imported. Raw and cooked homemade-style diets were mainly prepared with human-grade ingredients in a physical format like human food with water content of between 67% and 87%. Eleven products were selected from among those written on product labels, packages, and web detail pages with phrases that pet owners might think are "maintenance diets" because there is no legal obligation to indicate nutritional adequacy statement on the label in Korea. Eight products indicated that they could be fed as "maintenance diets" and two products indicated that "they could be fed separately or together with dry foods," and one product was vaguely marked with a word, "meal" that

Table 1. Ingredient lists of products

Product	Ingredients list	Description
A	Chicken, Sweet potato, Cabbage, Sweet pumpkin, Carrot, Broccoli	Human-grade, stored in a frozen
B	Chicken breast, Chicken tenderloin, Sweet potato, Cabbage, Sweet pumpkin, Chicken feet, Carrot, Broccoli	Human-grade, stored in a frozen
C	Chicken, Bellflower extract, Dried pollack, Sweet potato, Sweet pumpkin, Potato, Cabbage, Carrot, Egg, Beef liver, Apple, Banana, Spinach, Flaxseed, Broccoli, Vitamin (A, D3, E), Omega-3, Omega-6	Human-grade, stored at room temperature
D	Chicken, Sweet potato, Cabbage, Sweet pumpkin, Carrot, Broccoli	Human-grade, stored at room temperature
E	Chicken, Sweet potato, Potato, Chickpeas, Carrot, Cabbage, Paprika, Squash, Kale, Bok choy, Broccoli, Apple, Cauliflower, Brewer's yeast, Burdock powder, Lecithin, Egg shell powder, Kelp powder, Flavonoids, Spirulina powder, Vitamin, and mineral mixture	Human-grade, stored at room temperature
F	Purified water, Chicken, Pork liver, Canola oil, Wheat gluten, Carrot, L-theanine, Vitamin and mineral mixture, Carrageenan, Xanthan gum	Human-grade, raw, stored in a frozen
G	Salmon, Beef, Chicken breast, Rice, Carrot, Beef liver, Sweet potato, Pumpkin, Seaweed, Turmeric, Red ginseng, Vitamin and mineral mixture, Choline chloride	Human-grade, stored at room temperature
H	Chicken breast, Chicken leg meat, Chicken heart, Chicken liver, Chicken thigh bone, Pumpkin, Carrot, Apple, Dried pollack, Stone flower, Cottage cheese, Chia seed, Psyllium husk, Iodine salt, Flaxseed oil, Lecithin, Omega-3, Vitamin B, Vitamin E, Mineral mixture	Human-grade, stored at room temperature
I	Chicken, Chicken broth, Sweet potato, Canola oil, Guar gum, Calcium phosphate, Flavor, Salt, Calcium sulfate, Potassium chloride, Minerals, Vitamins, Choline chloride, Carrageenan	Human-grade, stored at room temperature
J	Chicken heart, Tomato, Chicken stomach, Chicken meat, Chicken liver, Pear, Amaranth, Sorghum, Beet root, Celery stalk, Coconut powder, Flaxseed oil, Eggshell powder, Brewer's yeast, Basil, Chives, Diatomite, Seaweed, Sea salt, Rosehip, Vitamins E3, Copper, Zinc, Iodine, Vitamin E	Human-grade, stored at room temperature
K	Meat and derived protein (chicken, pig), Fish and derived protein (salmon), Plants (powdered cellulose, marigold extract), Corn, Oils and fats (fish oil, sunflower oil), Mixed mineral substances, Vitamin D3, Iron, Iodine, Copper, Manganese, Zinc, Zeolite	Conventional wet food, stored at room temperature

The ingredient lists and description of 11 analyzed products. Human-grade means ingredients like human food.

could be confused with maintenance diets. The main meat source was unified as chicken. Ingredients listed on product packages are summarized in **Table 1**.

Nutrient analysis

All products, including products that could be stored at room temperature, refrigerated products, and frozen products, were delivered to the analysis laboratory. Refrigerated and frozen products were packed in ice packs and delivered to the analysis laboratory within 4 h. Proximate compositions (e.g., moisture, crude proteins, crude fats, crude fibers, and ash) and 10 minerals (except chloride and iodine) were analyzed following standard methods recommended by the Association of Official Analytical Chemists (**Supplementary Table 1**). Eleven amino acids (except tryptophan) were analyzed by high performance liquid chromatography (Ultimate 3000; Thermo Dionex, USA). Five fatty acids (e.g., linoleic acid, arachidonic acid, alpha-linolenic acid, eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]) were analyzed by gas chromatography (Agilent7890A; Agilent, USA) in the National Instrumentation Center for Environmental Management of Seoul National University (**Supplementary Tables 2** and **3**). All analyses were tested three times per sample. Results are presented as mean and standard deviation values. Vitamins and several nutrients (e.g., tryptophan, chloride, iodine) were excluded for technical reasons because it was difficult to guarantee their measurement accuracy. All measurement values were converted to energy density "g per 1,000 kcal ME" to compare with AAFCO dog nutrient profiles [22]. Energy density (ME/kg) of analyzed samples was calculated with the modified Atwater equation [23,24]:

$$\text{Metabolizable Energy (ME/kg)} = (3.5 \times \text{Crude Protein, g}) + (8.5 \times \text{Crude Fat, g}) + (3.5 \times \text{Nitrogen-Free Extract, g})$$

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RESULTS

All data of 11 samples were converted to "g per 1,000 kcal ME" to compare with AAFCO nutrients profiles for adult dogs (**Tables 2** and **3**). Energy density (ME/kg) was calculated according to the modified Atwater equation.

Crude protein and amino acids in all 11 products met AAFCO nutrient profiles for adult dog maintenance. Their values were higher than AAFCO adult dog nutrient profiles (**Table 2**). Crude fat also satisfied AAFCO nutrient profiles for adult dog maintenance in all 11 products, similar to results of protein analysis (**Table 2**). Particularly, EPA and DHA were not detected

Table 2. Nutrient values of crude protein and crude fat as converted to g per 1,000 kcal ME and comparison with AAFCO dog nutrient profiles

Nutrients	Units per 1,000 kcal ME	AAFCO		Summary of analysis			Results of 11 analyzed products										
		Adult maintenance minimum	Maximum	Mean	SD	Range	A	B	C	D	E	F	G	H	I	J	K
Crude protein	g	45.0		119.7	46.0	62.9–213.5	67.3	156.7	62.9	106.9	156.5	150.5	87.9	106.0	213.4	82.8	104.5
Arginine	g	1.28		6.8	3.1	3.1–12.7	3.5	10.5	3.1	5.2	8.5	9.7	4.3	6.2	12.7	4.8	5.6
Histidine	g	0.48		2.5	1.4	1.0–5.6	1.0	3.6	1.0	1.8	3.2	3.5	2.0	2.6	5.6	1.5	2.1
Isoleucine	g	0.95		4.7	2.4	2.0–9.3	2.0	7.0	2.0	3.7	5.9	6.6	3.8	4.9	9.3	2.0	3.5
Leucine	g	1.70		7.7	3.6	3.6–14.8	3.6	11.1	3.4	5.8	9.4	10.7	6.7	8.1	14.8	4.1	6.9
Lysine	g	1.58		6.5	4.2	2.0–14.8	2.1	10.6	2.3	4.8	7.8	10.7	4.0	7.2	14.8	2.0	4.8
Methionine	g	0.83		2.9	1.6	1.2–6.0	1.5	4.7	1.2	2.5	3.7	4.3	1.5	2.6	6.0	1.8	2.3
Methionine-cystine	g	1.63		3.7	1.9	1.6–7.4	1.9	6.0	1.6	3.2	4.5	5.7	2.1	3.4	7.4	2.5	3.3
Phenylalanine	g	1.13		4.2	1.8	1.9–7.7	2.0	5.9	1.9	3.1	5.3	5.7	4.1	4.3	7.7	2.3	3.9
Phenylalanine-tyrosine	g	1.85		7.0	3.3	2.1–13.7	3.2	9.7	3.1	5.1	8.3	10.0	6.7	7.3	13.7	3.8	6.2
Threonine	g	1.20		4.3	2.1	1.9–8.4	1.9	6.6	2.0	3.3	5.2	6.0	3.3	4.6	8.4	2.3	3.6
Valine	g	1.23		4.9	2.4	2.2–9.4	2.2	7.4	2.2	3.8	6.2	6.9	4.3	5.3	9.4	2.2	4.6
Crude fat	g	13.8		53.5	25.1	10.6–89.9	84.2	22.9	89.9	50.2	10.3	55.3	80.4	49.9	33.6	50.2	59.1
Linoleic acid	g	2.80		7.8	4.6	2.8–18.4	10.5	3.2	9.3	10.1	2.8	6.9	18.4	3.5	3.9	8.6	8.3
Alpha-linolenic	g	ND		0.9	0.6	0.3–2.0	0.5	0.3	0.4	0.3	0.3	0.7	1.7	1.4	0.7	2.0	0.9
EPA + DHA	g	ND		0.3	0.7	0.0–2.2	0.0	0.0	0.0	0.0	0.0	0.6	0.0	2.2	0.0	0.0	1.2
Omega-6:Omega-3			30:1			1:1–32:1	22:1	12:1	22:1	32:1	10:1	6:1	11:1	1:1	6:1	5:1	4:1

Results of analyzed products are converted into g per 1,000 kcal ME based on calculated energy density (ME/kg) using modified Atwater equation (3.5 kcal/g of protein and carbohydrates, 8.5 g/g of fat) recommended by the AAFCO. Tryptophan was excluded from analysis for technical reasons. Blue colored cells mean values below the AAFCO minimum requirements. Orange colored cell means values above AAFCO maximum requirements.
AAFCO, Association of American Feed Control Officials; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid; Omega-6:Omega-3, (linoleic + arachidonic):(alpha-linolenic + eicosapentaenoic + docosahexaenoic) fatty acid ratio; ND, not determined.

Table 3. Nutrient values of minerals as converted to g per 1,000 kcal ME and comparison with AAFCO dog nutrient profiles

Nutrients (minerals)	Units per 1,000 kcal ME	AAFCO		Summary of analysis			Results of 11 analyzed products										
		Adult maintenance minimum	Maximum	Mean	SD	Range	A	B	C	D	E	F	G	H	I	J	K
Calcium	g	1.25	4.5	2.8	2.6	0.4–9.5	0.5	1.7	0.4	0.9	2.3	3.4	4.0	1.4	3.9	3.3	3.7
Phosphorus	g	1.00	4.0	2.2	1.4	1.0–5.9	1.3	2.2	1.1	1.0	1.9	2.8	2.3	2.1	2.9	1.3	2.8
Ca:P ratio		1:1	2:1			0.3:1–2.6:1	0.3:1	0.8:1	0.4:1	0.9:1	1.2:1	1.2:1	1.7:1	0.7:1	1.4:1	2.6:1	1.4:1
Potassium	g	1.50		2.2	0.9	1.3–4.1	1.4	3.2	1.4	1.8	3.9	1.7	3.2	1.3	2.6	1.9	2.4
Sodium	g	0.20		1.2	1.3	0.3–4.8	0.9	0.4	1.0	0.3	0.3	0.6	1.0	2.3	1.3	0.6	1.9
Magnesium	g	0.15		0.3	0.1	0.2–0.5	0.4	0.3	0.3	0.1	0.4	0.4	0.4	0.2	0.3	0.4	0.3
Iron	mg	10		31.7	20.3	8.6–67.3	14.3	8.7	12.5	8.6	27.8	45.7	42.7	21.9	55.2	44.2	55.8
Copper	mg	1.83		2.1	1.5	0.6–5.0	0.7	1.0	0.7	0.6	2.3	3.5	1.8	2.9	3.5	5.0	5.0
Manganese	mg	1.25		5.0	2.8	1.9–9.7	9.7	1.9	6.8	1.5	7.5	3.2	3.8	4.7	2.8	4.5	4.9
Zinc	mg	20		35.1	32.4	5.4–109.4	8.7	8.5	7.1	7.1	24.4	31.4	33.1	26.9	109.4	71.8	5.4
Selenium	mg	0.08	0.5	0.0		0.0–0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Results of analyzed products are converted into g per 1,000 kcal ME based on calculated energy density (ME/kg) using modified Atwater equation (3.5 kcal/g of protein and carbohydrates, 8.5 g/g of fat) recommended by the AAFCO. Chloride and iodine were excluded from analysis for technical reasons. Blue colored cells mean values below the AAFCO minimum requirements. Orange colored cell means values above AAFCO maximum requirement.
AAFCO, Association of American Feed Control Officials.

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at all in 7 (63.6%) of 11 products. One (9.1%) of 11 products exceeded AAFCO maximum for omega-6 to omega-3 fatty acid ratio (**Table 2**).

In mineral analysis, none of the 11 products met the minimum requirements of AAFCO guidelines for all analysis items (**Table 3**). Selenium (90.9%, 10/11) was the mineral that was below AAFCO guidelines the most frequently in 11 analyzed products, followed by copper (45.5%, 5/11), zinc (45.5%, 5/11), potassium (27.3%, 3/11), calcium (27.3%, 3/11), iron (18.2%, 2/11), and magnesium (9.1%, 1/11) (**Table 3**). Regarding the ratio of calcium to phosphorus, six (54.5%, 6/11) of 11 products did not meet the AAFCO nutrient profiles for adult dog maintenance (**Table 3**).

DISCUSSION

Due to recent steep growth of pet industry, interests in new types of pet foods have been increased. In line with these changes, 11 new types of dog foods including raw and cooked homemade-style diets were analyzed and evaluated for the nutritional adequacy based on the AAFCO dog nutrient profiles. As a result, three of the samples (product F, G, I) met the AAFCO recommendation except selenium. Selenium is the mineral which has two faces of selenium-deficiency and toxicity according to Koller [25], which severe deficiency can lead cardiomyopathy and muscular weakness and pain in dogs. On the other hand, selenium should not exceed 0.5 g per 1,000 kcal ME according to the AAFCO recommendation. In dogs, 7.2 mg/kg of dietary organic selenium or 10 mg/kg of sodium selenite were toxic with clinical symptoms of impaired growth [26]. In dogs diagnosed with cardiomyopathy in 1979 [27], symptoms of selenium and vitamin E deficiency were reported and, but no cases were found in dogs that showed symptoms of selenium deficiency [28]. Therefore, it is highly likely that not only domestic companies, but also multinational companies have refrained from adding selenium due to concerns about excessive supply.

Another three samples (product E, K, L) almost satisfied the AAFCO standard except 1 to 2 criteria and 45.5% of the samples (5/11) did not meet the AAFCO standards due to a lack of 3 to 8 criteria including some minerals, Ca:P ratio and omega-6:omega-3 ratio. Especially, selenium, zinc, copper, and calcium were the most deficient minerals in terms of the frequency and degree of deficiency (**Table 3**).

Zinc was deficient in 45.5% of the 11 samples (5/11) in this study and the level of shortfall was also significant, ranging from 56%–73% compared to the AAFCO minimum amount. Similar, zinc was also one of the minerals with a higher frequency of levels below recommended intake for dogs in other studies [20]. Zinc plays important roles in dogs which is involved in several diverse physiologic functions and clinical signs include alopecia and lesions on mucocutaneous junctions, and in histology, parakeratosis [29]. Therefore, regarding feeding homemade-style foods to dogs as maintenance diets, it is important for veterinarians and pet owners to pay special attention to the zinc levels.

Copper was also deficient in 45.5% of the 11 samples (5/11) in this study, but clinical importance due to the deficiency seems to be lower compared to zinc. Because naturally occurring copper deficiency has not been identified as a main cause of canine disease [30]. In a study investigating the correlation between the frequent recognition of copper associated hepatitis and an increase in [Cu]H, quantitative hepatic copper concentrations in dogs [31],

the author said that this phenomenon is related to the fact that, AAFCO changed its guidelines in 1997 to use copper sulfates or chelates with high bioavailability instead of copper oxide with low bioavailability despite of no evidence to suggest clinical copper deficiency.

The Ca:P ratio imbalances were observed in this study, five of the 11 samples were below 1:1 and one of the 11 samples were over 2:1 (**Table 3**). The AAFCO recommends a ratio of calcium to phosphorus of 1:1 to 2:1. And calcium was deficient in 27.3% of the 11 samples (3/11). According to previous studies, there is a growing imbalance of calcium, phosphorus, and vitamin D as the number of dogs and cats on homemade diets increases [32]. In addition, research have shown that 20%–60% of raw diets have exhibited calcium, phosphorus, and vitamin D deficiencies [33]. A diet deficient in calcium, but adequate in phosphorus can cause secondary hyperparathyroidism and calcium excess can have serious consequences in rapidly growing puppies, especially in large and giant-breeds [29]. Therefore, veterinarians and pet owners pay special attention to the calcium levels for homemade-style diets like zinc.

In general, minerals should be supplemented by artificially adding premix by manufacturers rather than originating from raw materials. Burdett et al. [34] has mentioned that pet food formulation practices of manufacturers still need to be developed. Based on an up-to-date database, manufacturers should consider precise mineral premix.

Crude protein and crude fat satisfied the AAFCO recommendation in the majority products except product D (high omega-6:omega-3 ratio over the AAFCO maximum) and product E (low crude fat level below the AAFCO minimum) (**Table 2**). In addition, EPA and DHA were not detected in seven out of 11 (63.6%). Although omega-3 fatty acids are not determined for essential nutrients, many nutritionists pay attention to their anti-inflammatory effects and beneficial effects on pet's health such as skin problems, cardiovascular disease, and renal insufficiency [34-36]. One study has suggested the ideal omega-6 to omega-3 essential fatty acids ratio for canine atopic dermatitis is 5:1 to 10:1 [37].

One of the possible reasons for such elevated levels of crude protein and crude fat might be compositions of products. Instead of using grains (such as corn and rice), meat and vegetables are major sources in raw and cooked homemade-style foods (**Table 1**).

>Remillard [38] also mentioned that most homemade diet recipes have excessive protein because of the perception of pet owners that most dog food should be meat-based.

A limitation of this study was that only 11 samples were analyzed. In addition, several nutrients (e.g., vitamins, tryptophan, chloride, and iodine) could not be analyzed due to technical reason. Nevertheless, our research presented an overall nutritional tendency of recently emerging new alternative types of dog diets with a physical format like human food which are commercially available.

It was concluded that all foods analyzed had one or more nutrients below the AAFCO recommended levels although three to six products (26.2%–54.5%) almost met the AAFCO standard except one to two criteria. The data suggest a need for accurate nutritional adequacy statement for pet owners because they have the ultimate obligation to ensure their animal have proper nutrition throughout their life. Furthermore, the long-term influences of feeding homemade-style diets should be studied.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1

Method of analysis of macronutrients and minerals

Click here to view

Supplementary Table 2

Method of amino acid analysis

Click here to view

Supplementary Table 3

Method of fatty acid analysis

Click here to view

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