Homemade diet for a Dalmatian dog with dilated cardiomyopathy

Introduction

Dilated cardiomyopathy (DCM) is commonly associated with genetic predispositions in certain dog breeds but may also occur secondary to diseases or due to nutritional deficiencies (McCauley et al., 2020). As clinical signs of DCM only become evident when the heart function is already progressively compromised, early echocardiographic screening of dogs at risk is recommended (McCauley et al., 2020; Vollmar, 1999). Dogs with clinically inapparent DCM commonly show a decreased systolic function and an enlarged left atrium (Vollmar, 1999). Further diagnostic workup may include electrocardiogramm evaluation, holter monitoring over 24 h and the measurement of cardiac biomarkers (McCauley et al., 2020). Especially large dog breeds such as Doberman, Irish Wolfhound, Great Danes, and Boxers are at elevated risk for development of DCM (Simpson et al., 2015; Tidholm et al., 2001). Even though Dalmatians are not considered a dog breed at high risk for DCM, cases of male Dalmatians on a diet for urate urolithiasis prevention were reported, however, causality was not proven in this study (Freeman et al., 1996). According to an epidemiological investigation of urolith samples from the years 1985 to 2006 evaluating samples from a North American laboratory, the most frequently occuring uroliths in descending order were struvite, calcium oxalate, apatite and urate uroliths (23.8% of the samples) (Low et al., 2006). These proportions changed, and urate uroliths (14.9% of all samples) were the third most frequently diagnosed urolith type in the same laboratory during the years 2006 and 2018 (Kopecny et al., 2021). Dalmatians were identified as the breed with the highest risk to develop urate containing uroliths (Kopecny et al., 2021; Low et al., 2006). Urate containing uroliths are more often submitted by owners of younger dogs as well as female dogs (Kopecny et al., 2021; Low et al., 2006). Normally, purines are catabolized to xanthine and subsequently to uric acid which is converted to allantoin, which is soluble in the urine (Queau, 2019). Due to a mutation in the SLC2A9 gene, causing an inefficient transport of uric acid in both the liver and renal tubule, all Dalmatians are hyperuricosic, an autosomal recessive trait for which all dalmatians are homozygotous (Bannasch et al., 2008). To prevent urate urolith formation, water intake should be encouraged, the purine content of the diet should be limited, and an acidic pH should be avoided (Queau, 2019). In case of lower urinary tract urate urolith formation without obstruction, medical dissolution (xanthine oxidase inhibitor e.g. allopurinol) along with a purine-restricted, alkalizing diet, can be applied (Lulich et al., 2016).

Clinical report

A female, non-spayed Dalmatian (3 years old at time of presentation; bodyweight 20 kg, body condition rated as ideal by the owner, unfortunately no body and muscle condition score measurements were performed by the referring veterinarian at admission) was referred to the Institute of Animal Nutrition of the Vetsuisse Faculty, University of Zürich after being diagnosed with fully compensated DCM. The dog was previously presented to the cardiology unit of the Vetsuisse Faculty, University of Zurich for a preventive examination. At this timepoint, the dog was asymptomatic, no heart murmur was detected, hematology and blood biochemistry as well as an electrocardiographic examination were considered within the physiological ranges. No family background of DCM was reported. Cardiac troponin I (cTnI), a marker for heart myocardial injury (Oyama and Sisson, 2004), was within the normal reference range. In the ultrasound examination, the left atrium and ventricle appeared slightly enlarged and the systolic function of the left ventricle was slightly reduced. A trivial mitral valve insufficiency due to an annulus dilatation was found with the colour flow Doppler. Taurine was evaluated 5 months (T_{-5}) and 1 months (T_{-1}) before the patient's referral to the Institute of Animal Nutrition and showed a decrease from 168 µmol/L (T_{-5}, measured in plasma) to 72 µmol/L (T_{-1}, measured in serum; reference interval: 44 – 224 µmol/L). The dog was fed a homemade diet since switching from the puppy food with approximately 1 year of age. The main constituents included meat (lamb, chicken, beef), various vegetables, cheese, apple, egg, noodles, vegetable flakes (Table 1, diet A).

Due to the clinical findings and the atypical presentation for a primary DCM, a secondary nutritive genesis was suspected. Further differential diagnoses included infectious causes, metabolic/endocrine causes or a tachycardia induced cardiomyopathy, all of which seemed unlikely due to the clinical presentation of the dog. As Dalmatians have an increased risk for urate urolith formation, the owner furthermore requested the formulation of a diet to prevent the formation of urate calculi. A drawback is, however, that the urine of the dog has not been examined and at the timepoint of nutritional consultation it was unclear if uroliths are currently present.

Diet check

The ingredients of Diet A (fed prior referral) and Diet B (recommended diet) are detailed in Table 1. The nutritional contents of the patient´s subsequent diets are specified in Table 2 and were calculated with DietCheck Munich ©2005 Version 3.0 (RV Software; based on NRC 2006, modified by Dobenecker and Kienzle). The recommended nutrient levels by DietCheck correspond to the recommended allowance (RA) of the respective nutrient. Deviations of the recommendation by DietCheck Munich ©2005 from the RA for dietetic reasons are specified in Table 2

Before formulating a new ration for the patient, diet A was checked for nutritional adequacy. The energy content of diet A covered 90% of the calculated daily metabolizable energy (ME) recommendation (calculated as 130 kcal · kg $BW^{0.75}$ (NRC, 2006); Table 2) for a dog with an ideal body weight of 20 kg. As the dog was able to retain a stable bodyweight with this energy intake, the prescribed diet (Diet B) was calculated to meet the same ME-level.

Diet A did not meet the RA of calcium (Ca; 48 % of RA), while meeting the phosphorous (P) requirement thus resulting in an inverse Ca/P-ratio of 0.6 (reference frame for adult dogs: Ca/P= 1 to 2). The RA for magnesium was not fully met (78%, however the minimal requirement (MIR) as specified by the NRC 2006 was covered 2.6 times).

With regard to trace elements copper (55% RA), zinc (65% RA), manganese (40% RA) and iodine (5% RA) were not safely covered in the previously fed ration. However, levels of trace minerals are likely to be slightly underestimated in the diet check of diet A, as no analytical values were available for the two dry foods used as a treat and the dried vegetable mix (these components equal 7% of the daily ME requirement of the dog). No MIR is available (NRC, 2006) for trace elements with the exception of iodine. All other minerals (potassium, sodium, chloride, iron) met the RA in diet A.

Moreover, vitamin A (50% RA), D (25% RA), E (74% RA, 50% of the elevated recommendation for patients with heart disease by DietCheck Munich ©2005), B2 (70% RA), B12 (91% RA) were not safely covered in the diet. All other vitamins reached levels above the RA in diet A. Pantothenic acid met the RA for healthy adult dogs, however was slightly below the recommendation given by DietCheck Munich ©2005 Version 3.0 for dogs with chronic heart disease.

The RA for essential fatty acids were met, but the RA for EPA and DHA was not fulfilled by the diet (54% RA). However, the exact fatty acid composition of the dry dog foods used as a treat and the dried vegetable mix were not available. An underestimation of EPA and DHA is however unlikely as the mentioned ingredients contained neither fish nor algae.

Diet recommendation

Diet B was prescribed in order to support the dog’s cardiac health, to prevent urate urolith formation and to balance nutritional inadequacies (e.g. calcium-phosphorus ratio) from diet A. The main dietary ingredients in the order of their contribution towards the daily nutrient recommendation were: de-hulled rice, beef meat (goulash 22% fat), potatoes, tofu, egg, wheat germ oil, dried beef meat (17% fat), omega 3 supplement, carrots, and a mineral-vitamin supplement, a taurine supplement, and a carnitine supplement.

As described above, the energy content of the prescribed diet matched the daily ME content of diet A, as the dog was able to retain a stable body weight on this diet. Compared to diet A, diet B contained less protein (diet A 16 g crude protein/MJ ME; diet B: 13 g CP/MJ ME); more digestible carbohydrates approximated by nitrogen-free extract (NfE; diet A: 16.7 g NfE/ 100g DM; diet B: 47.3 g NfE/ 100g DM), and less crude fat (CF; diet A: 35.6 g CF/ 100 g DM; diet B 20.5 g CF/ 100g DM).

The following principles were taken into consideration when formulating diet B:

In order to prevent urate urolith formation, dietary protein should be kept close to the requirement and dietary purines were reduced by covering part of the protein requirement with low purine ingredients. Diets promoting acidic urine should be avoided as urate uroliths are less soluble in acidic urine (Queau, 2019). The calculated urinary pH for diet B was 7.0. Highly digestible protein (115% of the recommended value by DietCheck) was included in the diet and enough protein to prevent muscle mass loss, which has to be considered in chronic heart insufficiency patients, especially if the patients decompensates which was currently not the case. High purine content can be found in yeast products, liver, brain and kidneys whereas egg, tofu, and milk-based products are low in purines. In detail, 43% of the protein content in diet B originated from beef meat, whereas 57% mainly originated from tofu, egg, rice and potatoes. The drawback in this case is that low protein and low purine feedstuffs are usually also low in taurine. However, methionine and cysteine are important precursors of taurine which makes egg a good option for this case. In diet B the sum of methionine and cysteine RA is covered by 104% of which 22% are covered by egg, which on the other hand only accounts for 13% of the crude protein in the diet. Nevertheless, additional taurine was administered in this case, as anamnesis suggested a nutritional genesis of the heart insufficiency.

Carnitine was supplemented to the diet in order to facilitate the transport of fatty acids, the main energy source of the heart muscle, in form of acyl-carnitine-esters across the mitochondrial membrane (Hand et al., 2010; Pion et al., 1998). Moreover, association between carnitine deficiency and development of DCM were reported in the literature (Keene, 1991).

Existing supply gaps of minerals and vitamins were compensated by adding an appropriate vitamin-mineral supplement. Special care was taken to correct the earlier inadequate Ca-P-ratio and supply (diet A). The Ca-P-ratio in diet B is with 1.4 in the ideal range for an adult dog and the RA of Ca and P were covered, while avoiding over-supplementation. Furthermore, the sodium content was kept close to the recommended requirement in diet B, however it was not explicitly reduced as the dog has no signs of edema (Zentek, 2016). Adequate potassium and magnesium levels, in line with the recommendations for patients with chronic heart insufficiency, were supplied (Hand et al., 2010). Moreover the fatty acid profile of the ration was adapted towards a smaller omega 6 to omega 3-ratio and n-3 polyunsaturated fatty acids (EPA, DHA) were supplemented in the form of a capsule for their cardioprotective and membrane fluidity altering effects (Hand et al., 2010; Ramadeen et al., 2010; Stubbs and Smith, 1984; Zentek, 2016). Increased levels of vitamin E, acting as an antioxidant, were provided in the diet (270% RA), which is close to the recommendation of Zentek, 2016 for dogs with chronic heart insufficiency. Large parts of vitamin E supply in the diet derived from the mineral-vitamin-supplement (55% of the supply) and wheat germ oil (32% of the supply).

The owner was advised to strictly adhere to the prescribed amounts of each feedstuff and supplements and to report changes in body weight of the dog, which would indicate that an adaptation of the ME supply might be necessary. Moreover, the importance of the correct fat content of the meat components used in diet B was stressed, as ME content and, in this case most importantly, protein content would vary with co-varying fat content in the product. This could ultimately lead to higher protein content and therefore higher purine content in the diet which could adversely affect urolith formation.

For hygienic reasons we advised the owner to cook the meat and to include the cooking water of meat and rice in the diet to 1) promote fluid uptake and 2) prevent loss of watersoluble B-vitamins with the cooking water. It was clearly stated that the cooking water of the potatoes should not be fed to the patient as it might contain elevated levels of solanin and toxicity cannot be excluded. The owner was advised to avoid feeding the egg in its raw form as avidin in the egg white might interfere with biotin supply in the diet, even though this was not considered to be a major problem as diet B is actually very rich in biotin.

Follow up was limited after the consultation as the owner did not come back with specific questions. After 4 months, the cardiac function was re-examined in the small animal clinic of the University of Zurich. The systolic function of the left ventricle was slightly decreased and no clear DCM could be diagnosed which was a slight improvement compared to the previous examination. The dog had gained weight (700g) but maintained an ideal body condition (BCS 4.5/9). The owner had modified the prescribed daily ration and included several other protein sources (e.g. chicken carcass, beef rumen, rabbit meat; the complete list of ingredients is available in Table 1, Diet C). The amount of protein in the diet was increased (134 % RA) compared to the recommendation (Diet B). The energy content of the diet was increased by the changes the owner does in the daily ration. Moreover, the owner only administered half of the prescribed taurine dose after feeding the full dose for the first three weeks, 75% of the prescribed carnitine dose and half of the prescribed dose for the EPA & DHA supplement. However, as the mineral-vitamin supplement was used, all major nutrients except potassium and chloride were covered. As a result, 3 alternative diet adaptations (diet D1-3) were formulated with the goal to meet the nutritional requirements of the dog, prevent urate urolith formation and support cardiac health while incorporating some of the ingredients used in diet C in order to increase owner compliance.

Discussion

The major challenge in this case was limited owner compliance to adhere to the prescribed diet which may be due to the limited number of ingredients in diet B compared to the previously fed diet A. Reducing purine content, which was achieved by using tofu and egg to cover parts of the protein requirement of this dog, played a major role to fulfil the criteria of a urate urolith preventing diet. To prevent excess of protein while keeping diet B isocaloric to diet A, potatoes and rice were added resulting in a large part of the calories being covered by digestible carbohydrates. Unfortunately, both the pH and potential crystals in the urine were unknown at the time-point of introduction of the new dietary recommendation, therefore further refinement of the diet with regards to urolith prevention was not possible. This would have been important, as not all adult Dalmatians develop urate stones, even if they show urate crystalluria as a puppy (Bartges et al., 1999). In the present case the protein content originating from meat or slaughtering by-products in diet C was above the originally recommended level. Even though the owner fed a diet which exceeded the recommended protein level, the dog did not develop clinical signs of urate urolithiasis. However, the owner fed products such as rumen and parts of whole chicken carcasses, containing less digestible connective tissue protein. Due to the lower digestibility of these products compared to muscle meat, it remains questionable how much of the protein was actually absorbed from the gut and therefore could have increased the risk for urate urolith formation. Nevertheless, feeding less digestible protein sources should be avoided as they may negatively impact the gut microbiota and promote the formation of unfavourable metabolites such as biogenic amines.

As the literature suggests, that carnitine and taurine supplementation may positively affect cardiac health in dogs with DCM, supplementing these two components was one of the main dietary strategies in this case, due to the required limitation in protein content.

Generally, for the evaluation of taurine status both whole blood and plasma samples should be evaluated simultaneously for taurine concentrations (Freeman et al., 2018; Sanderson, 2006), as a large part of taurine in blood is stored in blood cells and platelets (Vinton and Laidlaw, 1986). Unfortunately, whole blood taurine measurements were not available for this patient. However, as taurine was decreased in serum in the second measurement before dietary consultation of this patient, taurine supplementation deemed beneficial due to its modulating effects on tissue calcium, inactivation of free radicals, osmoregulation of the myocardium, direct effects on contractile proteins and serving as a natural antagonist of angiotensin II (Freeman et al., 2018; Sanderson, 2006).

The present case improved clinically after addition of taurine and carnitine to the diet, even though the diet recommendation was not followed strictly by the owner. However, it is suspected that the negative impact of inadherence to the dietary recommendation rather influences urate urolith prevention negatively due to changes in protein sources used, while taurine and carnitine supplements were still used by the owner and therefore could have impacted the heart health positively. Moreover, the increase in protein rich ingredients in the diet may have added further carnitine and taurine, depending on the actual digestibility of the used slaughtering by-products. At present, the β-aminosulfonic acid taurine is not considered as essential dietary nutrient in dogs fed adequate amounts of sulphur-containing amino acids (NRC, 2006). In the present case, diet A covered the RA of protein well and a large part of the protein was meat-based, therefore containing taurine. However, secondary effects of the diet decreasing the bioavailability of taurine, such as heating the ingredients and subsequent Maillard reaction (Kim et al., 1996), may play a role in development of DCM. Moreover, dietary fibre, especially fermentable fibre, interferes with protein digestion (Silvio et al., 2000), thus potentially decreasing the availability of precursors for taurine and carnitine synthesis. Specifically beet pulp in comparison to cellulose and rice bran, decreases taurine status in dogs by increasing fecal excretion of branched chain fatty acids and decreasing protein digestion (Ko and Fascetti, 2016). Diet A contained various sources of fermentable fibres, namely apple, beet pulp, courgettes and carrots. Both crude fibre and fermentable fibre content were reduced in diet B to rule out any potential negative effects on protein digestion and taurine availability and the owner adhered to the prescribed amounts of vegetables. However, the amount of vegetables had to be increased again in diet D1-3 due to its filling effect, as the dog was reported to be hungry. Nevertheless, care was taken to achieve a balanced amount of soluble (rich in carrots) and insoluble fibres (rich in fennel) in order to minimize the potential negative effects of over supplementing one specific fibre type.

In the past years, feeding grain-free diets was repeatedly associated with the development of DCM in dogs. Diet A contained only a very small amount of grains in the form of noodles. Dogs on a non-traditional diet diagnosed with DCM that were switched to a grain-containing diet again, had a significantly longer survival time (Freid et al., 2021). Grains were incorporated in the diet recommendations and where also fed by the owner (e.g. noodles, rice). However, except the factors discussed above (taurine, fibre), the link between diet and DCM is unexplained and the association between grain-free diets and DCM is currently a field of active research as the US Food and Drug Administration started investigations in this regard (FDA, 2018). Unfortunately, no taurine measurement was undertaken after dietary consultation. Therefore, the effect of the supplementation cannot be fully assessed.

Moreover, an association between carnitine deficiency and development of DCM (Keene, 1991) may have occurred in the present case. Carnitine is required for the transport of fatty acids across the outer membrane of mitochondria and is normally synthesized in adequate amounts from peptidyllysine after methylation and subsequent ascorbic-acid dependent hydroxylation (NRC, 2006). Carnitine is present in animal-based products, especially skeletal and cardiac muscles, but not in plant based products (Mansilla et al., 2019). Plasma concentrations of healthy dogs were reported in the literature (Neumann et al., 2007). However, no measurements of carnitine were available in the present case, as these are not included in standard blood diagnostics and may be more accurately monitored by biopsies (Mansilla et al., 2019). As the owner changed some of the main ingredients while sticking to the use of the prescribed supplements, the clinical improvement of the DCM is very likely to be associated with the use of supplementary taurine and/or carnitine in the diet. Due to change in nutrient supply the criteria for a urate urolith preventing diet were not strictly met and a dietary adaptation to fulfil the psychological needs of the owner was necessary. The effect of dietary alterations done by the owner remains unclear, as digestibility especially in slaughtering by-products such as rumen or parts of chicken carcass may vary. For a full workup of the effects of taurine and carnitine supplementation, serial diagnostic measurements would be necessary.

Conclusion

The present case highlights the nutritional management of a dog with a genetic predisposition for urate urolith formation being diagnosed with DCM phenotype (fully compensated). Nutritional management included balancing the partly contradictory nutritional requirements of both DCM and prevention of urate urolith formation and the targeted use of supplements (e.g. taurine, carnitine, poly-unsaturated fatty acids) supporting the clinical condition as substantiated by the scientific literature. A major drawback of the case remains however the limited diagnostic workup and limited owner compliance.

Tables and figures

Table 1: Quantity of ingredients in the diets per day. All values were converted to daily amounts based on the owner’s information and represent the raw weight. All values were converted to daily amounts based on the owner’s information and represent the raw weight.

Ingredient	Unit	Diet A	Diet B	Diet C	Diet D1	Diet D2	Diet D3
Lamb meat (18% fat)	g	107	/	/			
Chicken meat (10% fat)	g	107	/			120	
Beef (18% fat)	g	107	/				
Beef (22% fat, goulash)	g	/	90		150		
Rabbit meat (8% fat)	g	/	/	80			135
Egg (without shell)	g	17	60	60	60	60	60
Tofu	g	/	90	80	60	60	60
Beef rumen	g			80			
Chicken carcass	g			80			
Edamer cheese	g	40					
Dried vegetable mix [a]	g	4.2		2.1			
Millet	g			46.7		145	
Noodles	g	5.3		46.7			
Potatoes [b]	g	/	250		250		
Rice, polished	g	/	75	46.7	75		115
Carrots	g	45	30	30	100	100	100
Courgette	g	45	/				
Cucumber	g	45	/				
Beetroot	g	45	/				
Fennel	g				100	100	100
Apple	g	80	/				
Beef tallow	g			10			

Lard	g					20	25
Lineseed oil	g	3	/	4	2	5	5
Rapeseed oil	g	3	/	/			
Wheatgerm oil	g	/	8	4	7	4	5
EPA & DHA supplement [c, d]	pcs	/	2	1	1	1	1
Mineral & vitamin supplement [c, e]	g	/	7	7	6	7	7
L-carnitine supplement [c, f]	g	/	4	3	4	4	4
Taurin supplement [c, g]	pcs	/	2	1	2	2	2
Dry food 1 (as treat) [h]	g	9.3	/				
Dry food 2 (as treat) [i]	g	9.3	/				
Dry beef rumen (as treat)	g	11.4	/				
Ovendried beef (17% fat)	g	/	15				
bread (as treat)	g	/		17.1	17.1	17,1	17.1

Diet A was fed by the animal owner before consultation, diet B was recommended by the Institute of Animal Nutrition of the Vetsuisse Faculty, University of Zurich. Diet C was fed by the animal owner after consultation and included changes made by the owner, diet D1-3 are adapted diets based on ingredients fed by the owner as recommended by the Institute of Animal Nutrition of the Vetsuisse Faculty, University of Zurich.

[a] Product contains a mix of dried potato, parsnip, turnip, carrot, rutabaga, courgette, pumpkin and celery.

[b] The weight of the respective ingredient is taken after boiling.

[c] The ingredient should not be heated and therefore has to be added to the diet after cooling.

[d] Each capsule contains 500 mg EPA and 200 mg DHA.

[e] Mineral & vitamin supplement composition per 100g product: 19.8 g calcium, 6 g phosphorous, 1.2 g magnesium, 1.6 g potassium, 301 mg iron, 60 mg copper, 300 mg zinc, 37 mg manganese, 1.4 g chloride, 6.6 mg iodine, 35000 IU vitamin A, 3000 IU vitamin D, 300 mg vitamin E, 8.3 mg vitamin B1, 40 mg vitamin B2, 10 mg vitamin B6, 0.12 mg vitamin B12, 0.66 mg biotine, 56 mg niacin, 22.5 mg panthothenic acid

[f] The supplement contains 48 g of L-Carnitine per 100g product.

[g] The supplement contains 500 mg of taurine per tablet.

[h] Vegetarian dry food which is marketed as “grain-free”.

[i] Dry food containing insect protein

Table 2: Comparison of subsequent diets to the daily recommended allowance (RA) for a dog with 20 kg ideal body weight.

Item	Unit	RA[a]	Diet A	Diet B	Diet C	Diet D1	Diet D2	Diet D3
Energy; ME	MJ	**5.1**[b]	4.6	4.6	5.4	5.1	5.1	5.1
Dry matter	g	/	216	239	281	258	270	253
Moisture	g	100	469	395	319	559	373	383
Crude protein	g	52 [31]	74	60	77	58	60	58
Crude fat	g	[17]	77	49	65	56	61	60
NfE	g	/	36	113	122	122	125	117
Crude ash	g	/	9	15	15	16	15	13
Crude fiber	g	/	4.1	2.5	4.0	5.0	9.9	4.5
Methionine + cysteine	g	2.00	2.69	2.08	1.80	2.17	2.00	2.01
Taurine	g	/	0.1	1.4	0.9	1.4	1.4	1.4
Calcium	mg	1229	593	1615	2785	1432	1631	1614
Phosphorous	mg	922	1017	1120	1801	1118	1367	1151
Magnesium	mg	184	144	242	311	239	426	204
Potassium	mg	**1598** [1324]	1714	2507	1276	3036	1561	1754
Sodium	mg	**197** [248]	775	217	372	292	344	324
Chloride	mg	369	416	488	295	554	377	341
Iron	mg	9.2	10.3	32.3	37.4	29.2	38.4	27.4
Copper	mg	1.8	1.0	5.1	5.4	4.4	5.6	4.5
Zinc	mg	18.4	11.9	28.5	29.0	26.1	26.8	26.4
Manganese	mg	1.5	0.6	4.0	4.7	3.6	6.0	3.2
Iodine	µg	270	13	484	475	419	475	474
Vitamin A	IU	1552	778	3065	3041	2812	3235	3093
Vitamin D	IU	167	42	280	280	250	280	280
Vitamin E	mg	**14** [9.46]	7	38	34	36	35	37
Vitamin B1	mg	0.69	0.74	1.17	1.17	1.15	1.52	0.98

Vitamin B2	mg	1.60	1.12	3.57	3.35	3.20	3.56	3.34
Vitamin B6	mg	0.46	1.90	2.54	1.71	2.50	2.86	1.75
Vitamin B12	µg	11	10	12	20	11	9	23
Biotin	mg	2 [/]	34	75	78	70	87	70
Niacin	mg	5	18	21	18	18	17	17
Pantothenic acid	mg	**5.22** [4.63]	4.65	5.27	5.34	5.27	5.51	4.78
Linoleic acid [c]	g	[3.4]	5.18	5.73	10.27	7.21	11.86	10.65
α-Linolenic acid [c]	g	[0.13]	0.98	1.16	3.26	2.44	3.81	4.24
EPA & DHA [c]	g	[0.28]	0.15	1.51	0.93	0.76	0.85	0.90
calculated urinary pH [d]	pH	6.5 – 7.2 [d]	6.5	7.0	6.9	6.7	6.8	6.8

Abbreviations: EPA, eicosapentanoic acid; DHA, docosahexaenoic acid

[a] Recommended allowance (RA) as calculated with DietCheck Munich Version 3.0 for dogs with chronic heart insufficiency. Values in brackets [ ] show the respective RA as detailed by the NRC (2006) for adult dogs at maintenance in case of deviation of > 5% from the values given by DietCheck. Bold printed values differ for dogs with chronic heart disease from dogs at maintenace in DietCheck Munich Version 3.0.

[b] The daily metabolizable energy (ME) requirement specified by DietCheck Munich Version 3.0 for animals with chronic heart insufficiency matches the daily ME requirement for active pet dogs (NRC 2006) which is estimated to be 130 kcal · kg $BW^{0.75}$; conversion factor 1000 kcal = 4.184 MJ (FEDIAF, 2021). The daily ME requirement for inactive pet dogs (NRC 2006) would be 90 kcal · kg $BW^{0.75}$ = 898 kcal = 3.76 MJ. The daily energy intake of diet B was adjusted to meet the ME content of Diet A, as the dog was able to retain a stable body weight with 4.6 MJ ME.

[c] Values in the ration were calculated in a separate excel sheet. As no fatty acid composition was available from Dog Food 1 and 2, these values were not included in the calculation.

[d] Urinary pH of the diet was calculated according to the following formula (reviewed by (Kamphues et al., 2014); original publication by Schuhknecht and Kienzle 1992): pH = [(calcium · 0.5 + magnesium · 82 + sodium · 43 + potassium · 26) – (phosphorous · 65 + chlorid · 28 + methionine · 13.4 + cysteine · 16.6)] · 0.019 + 6.5; the nutrient contents in the formula refer to g/ 100 g dry matter. A reference urinary pH of 6.5 to 7.2 g should be achieved to prevent urate urolith formation (Kamphues et al., 2014; Zentek, 2016).

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