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ESTIMATION OF MAJOR NUTRIENTS IN DRY DOG FOODS AND THEIR COMPLIANCE WITH NUTRITIONAL GUIDELINES

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ABSTRACT

The aim of this study was to estimate complete extruded dry food for adult dogs, with a particular focus on the nutritional value with respect to current nutritional guidelines for dogs, dietary fiber fractions, the division into breed size. Dog foods were subjected to chemical analyzes to determine the content of basic nutrients and dietary fiber fractions. The material for the research consisted of 15 maintenance foods for adult dogs (five for large breed dogs, five for small breed dogs and five for all breeds dogs). All analyzed feeds met the European Pet Food Industry Federation recommended minimum recommended levels of protein and fat. Individual tested foods were characterized by different levels of dietary fiber fractions, such as acid detergent fiber (ADF), cellulose (CEL), hemicellulose (HCEL). The group of foods for small breed dogs was characterized by the lowest mean of ME (391.23 kcal per 100 g DM). A higher level of ME (393.99 kcal per 100 g DM) was observed in the group of foods for dogs of large breeds, and the highest (397.05 kcal per 100 g DM) – in the group of foods for dogs of all breeds.

Key words: breed size, complete feed, energy value, extruded dog food, fiber fractions, quality assurance

INTRODUCTION

Nowadays, dogs are usually equally treated with other family members. According to statistics reported by the Fédération Cynologique Internationale (FCI), the approximate total number of dogs (pure-breed or not) around the world is about 147 million. Due to the growing owners' awareness, the pet food industry is changing dynamically. In the nutrition of dogs are mainly used dry foods and their industry is still growing – annual growth rate of the pet food industry (average value over the past 3 years) is 2.6% [FEDIAF 2020b]. Currently, dog food is adjusted to the dog's age, lifestyle, physical activity and breed size [Di Donfrancesco et al. 2014]. Despite this, it is common that the animal' diet is not properly balanced. Despite the current dietary guidelines, feed often do not meet minimum recommended nutrient [Davies et al. 2017]. Owners usually make the mistake of choosing food that is not adjusted to the age and size of the dog properly. For example, a common problem is giving adult dogs of small breeds a puppy food, although dogs of these breeds mature faster than large breeds dogs [Posada et al. 2014]. According to legal regulations, a product marked as a complete/ maintenance food is balanced in such way that it can be the only source of food for the animal, without leading to nutrient deficiencies [EC 2009]. Many dogs are fed the same food for too long. As a consequence of humanizing domestic animals, dogs' owners emphasize the importance of choosing food from a trustworthy food producer. This is why it is necessary to evaluate the quality of pet food [Hill et al. 2009, Farcas et al. 2013, Kanakubo et al. 2015]. Currently, there are many studies conducted to verify the safety of dog food and comparing the results of the analyzes with the nutritional guides or the producer' declaration. FEDIAF [2020a] has established nutrition guidelines based on National Research Council (NRC) and scientific research. The dietary guidelines give minimum recommended levels for protein and fat, but not for carbohydrates. In most cases, carbohydrates should be the smallest part of a dog' diet [Hewson-Hughes et al. 2013]. Excess carbohydrate in the diet over a period of time is not harmful, however, in dogs with diabetes, increasing their intake may lead to hyperglycemia and increase insulin requirements [Elliot et al. 2012].

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Carbohydrates that are resistant to digestive enzymes in the dogs' and other monogastric animals' digestive tract (polysaccharides), and are not hydrolyzed in the small intestine but can be fermented in the large intestine, are called dietary fiber [Slavin 2008]. Too much consumption of foods rich in dietary fiber may lead to an increase in the volume of the stool and a slower passage of the chyme and – consequently – constipation. It has been shown that feeding a dog a diet rich in dietary fiber contributes to the reduction of protein digestibility and may delay the absorption of cholesterol and triacylglycerols [Silvio et al. 2000].

Thus, the aim of this study was to estimate complete extruded dry foods for adult dogs, with a particular focus on the nutritional value with respect to current nutritional guidelines for dogs, dietary fiber fractions and the division into breed size.

MATERIAL AND METHODS

Sample collection

The material for the study included 15 maintenance dry dog food products of various brands, which were purchased in local pet stores and online stores. All analyzed feeds were randomly chosen from the previously compiled inventory of extruded products, labeled as intended specifically for adult dogs: five for small breed dogs (S1–S5); five for large breed dogs (L1–L5); five for dogs of all breeds (A1–A5). The composition of the main ingredients of tested dog foods is shown in Table 1. The weight of collected bags were from the range of 1.2 to 3.0 kg. All bags were stored in laboratory room temperature (approx. 18–21°C) until analysis. From each bag, a representative sample was collected for laboratory analysis [ISO 2012]. Samples of feeds were ground in a laboratory mill type KNIFETEC 1095 (Foss Tecator, Höganäs, Sweden), placed in sterile containers and marked with the symbols A1–A5; L1–L5; S1–S5.

Chemical analyzes

The basic chemical composition was determined in the ground samples according to standard Association of Official Analytical Chemist methods [AOAC 2019]. To determine dry matter (DM), samples were dried at 105°C to a constant weight (and content of moisture – method 945.15). Crude protein (CP) (method 945.18) release was determined from 6.25 × total nitrogen measured by the Kjeldahl method using a Büchi Scrubber B414 digestion apparatus and a Büchi 324 distillation set (Büchi Labortechnik AG, Flawil, Switzerland). Crude fat (as ether extract, EE) was determined by the Soxhlet method with diethyl ether used as a solvent (method 945.16). The crude fiber (CF) was determined with an ANKOM220 FiberAnalyser (ANKOM Technology, New York, USA). Crude ash (CA) was determined by burning in a muffle furnace in 580°C for 8 hours (method 920.153). Nitrogen-free extracts (NFE) were calculated according to the formula:

$$\text{NFE(wet basis)(\%)} = 100 - (\%\ \text{moisture} + \%\ \text{CP} + \\ + \%\ \text{EE} + \%\ \text{CA} + \%\ \text{CF})$$

The content of fiber fractions was determined by the van Soest method [Van Soest et al. 1991]. This method differentiates the nutrient composition into the fractions: neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (CEL), hemicellulose (HCEL) and lignin with acid detergent (ADL). The determinations were made using the ANKOM^{220} FiberAnalyser (ANKOM Technology, USA). Neutral detergent fiber (NDF), as the sum of hemicelluloses, cellulose and lignin, was determined using sodium dodecyl sulfate (Merc 102342, Germany), and acid detergent fiber (ADF) composed of cellulose and lignin – with cetyltrimethylammonium bromide. Lignin (ADL) content was determined after ADF sample hydrolysis in 72% sulfuric acid (VI), while hemicellulose (HCEL) was calculated from the difference in NDF and ADF content, and cellulose (CEL) with the difference between ADF and ADL.

The results of basic chemical composition and fiber fractions are expressed as g per 100 g DM. The levels of all nutrients were compared with recommendations from FEDIAF [2020a] considering an energy intake of 110 kcal per kg body weight (BW)$^{0.75}$ for dogs with moderate activity (1–3 hours per day).

Energy value

The metabolizable energy (ME) value of dog food was calculated on the basis of the determined chemical composition. According to FEDIAF [2020a], for calculation of ME in prepared pet foods for cats and dogs (dry and wet) the following 4-step calculation has to be used:

Step 1 Calculate Gross Energy (GE):
$$\text{GE (kcal)} = (5.7 \times \%\ \text{CP}) + (9.4 \times \%\ \text{EE}) + \\ + [4.1 \times (\%\ \text{NFE} + \%\ \text{CF})]$$

Step 2 Calculate energy digestibility (%):
$$\%\ \text{energy digestibility} = 91.2 - (1.43 \times \%\ \text{CF in DM})$$

Step 3 Calculate digestible energy (DE):
$$\text{DE (kcal)} = (\text{GE (kcal)} \times \text{energy digestibility}) / 100$$

Step 4 Calculate metabolizable energy (ME):
$$\text{ME (kcal)} = \text{DE (kcal)} - (1.04 \times \%\ \text{CP})$$

Statistical analysis

The obtained results were statistically evaluated, and the average of individual features were calculated.

Table 1. Main ingredients of the tested dry dog foods

Product	Main carbohydrates sources	Main protein sources	Main lipids sources	Additives (nutritional and zootechnical)
A-1	white rice, brown rice, oat	turkey	turkey fat	YSE
A-2	potatoes	poultry, duck	chicken fat	beta-glucans, MOS
A-3	wholegrain cereals	products of animal origin	oils and fats	–
A-4	potatoes, sweet potatoes	salmon, lake trout	salmon oil	FOS
A-5	sweet potatoes, potatoes	bison, lamb, chicken	rapeseed oil	YSE
L-1	potatoes	white fish	chicken fat	MOS, FOS, YSE, glucosamine, chondroitin
L-2	oat, wheat	chicken	chicken fat	MOS, FOS, YSE, glucosamine, chondroitin, collagen
L-3	rice	lamb	salmon oil	MOS, FOS, YSE, inulin, glucosamine, chondroitin
L-4	corn	poultry	chicken fat	glucosamine, chondroitin
L-5	wholegrain wheat	beef	chicken fat	–
S-1	lentil	chicken, turkey	chicken fat	glucosamine, chondroitin
S-2	wholegrain wheat, corn	beef	poultry oil	–
S-3	barley	salmon, rabbit	chicken fat	YSE, glucosamine, chondroitin
S-4	wheat, corn	chicken, beef	animal fat	–
S-5	sweet potatoes, potatoes	beef	beef fat	FOS, MOS, glucosamine

A-1 to A-5 = all breeds; L-1 to L-5 = large breeds; S-1 to S-5 = small breeds; FOS = fructooligosaccharydes; MOS = mannooligosaccharides; YSE = *Yucca schidigera* extract.

Significant differences were calculated by one-way analysis of variance using the Duncan multiple range test using Statistica 13.1 [StatSoft Inc. 2016].

RESULTS AND DISCUSSION

Chemical Composition

Regarding basic composition, FEDIAF [2020a] provides the minimum recommended levels of protein and fat for complete pet food. Complete pet food is feed which, by reason of its composition, is sufficient for a daily ration. When formulating pet foods, manufacturers should not use a reference to minimum requirements but minimum recommended levels (MRLs) ensuring adequate nutrient intake as contained in update guide [FEDIAF 2020a]. MRLs are defined as the lowest intake that will support normal function, such as maximal growth rates or prevention of deficiency symptoms. Significant differences were discovered in the proportion of the tested components, depending on the tested dog foods (Table 2).

All tested dog foods met the recommended minimum levels (MRL) for crude protein and fat according to FEDIAF [2020a], which are 18 g and 5.5 g per 100 g DM of food, respectively. Protein is the most important nutrient because it determines the development of the body. It is necessary for the proper course of digestive processes, energy production, blood clotting, and muscle contraction [Cuesta et al. 2015]. Protein deficiency in the diet can lead to body weight loss. Individual tested foods were characterized by different levels of protein (Table 2). Significantly the lowest value was found in the group of feeds dedicated to large and giant breeds (average 27.68 g per 100 g DM). In this group, the evaluated foods contained proteins in the range 25.82–30.41 g per 100 g DM. In the group of food for dogs of all breeds, the average value of crude protein was 31.03 g per 100 g DM, while in the group of feeds dedicated for dogs of small breeds the average was 31.66 g per 100 g DM and the range was from 28.32 g per 100 g DM to 36.36 g per 100 g DM. The studies by Alomar et al. [2006] showed that the crude protein content of 59 tested dog foods was in the range from 16.43 g per 100 g DM to 39.04 g per 100 g DM and the average value was 26.23 g per 100 g DM. The results obtained in these studies were in a wider range [Alomar et al. 2006], some of the tested foods did not meet the required minimum level of protein – 18 g per 100 g DM, which means that despite the current nutritional guidelines, there are still foods that do not meet the minimum recommended levels of nutrients.

All the analyzed dog foods met the minimum recommended level of crude protein established by FEDIAF

Table 2. Chemical composition (g per 100 g DM) of the tested dry dog foods

Product	Moisture, %	Crude protein	Crude fat	Crude fiber	Crude ash	NFE
A-1	9.29	26.09	8.91	3.14	6.46	55.40
A-2	11.11	26.70	13.07	5.48	8.87	45.87
A-3	9.89	22.90	9.61	2.91	5.54	59.04
A-4	9.29	43.56	16.56	2.54	5.25	32.09
A-5	11.11	35.88	18.08	2.91	10.00	33.13
Mean[1]	10.14	31.03[a]	13.25[a]	3.40	7.22[a]	45.11[b]
L-1	8.70	30.41	22.60	3.13	9.99	33.88
L-2	11.11	28.10	12.11	3.41	10.00	46.38
L-3	11.11	25.82	13.00	3.49	5.98	51.72
L-4	11.11	26.13	10.05	2.26	10.00	51.56
L-5	11.11	27.95	11.36	2.97	10.00	47.72
Mean	10.63	27.68[b]	13.82[b]	3.05	9.19[b]	46.25[b]
S-1	13.64	36.36	15.24	5.42	10.00	32.99
S-2	11.11	31.80	12.81	2.76	10.00	42.64
S-3	11.11	28.32	11.43	1.64	10.00	48.62
S-4	11.11	30.97	13.84	2.68	10.00	42.50
S-5	8.70	30.85	17.84	4.47	10.00	36.85
Mean	11.13	31.66[a]	14.23[b]	3.39	10.00[b]	40.72[a]
MRL*	–	18.00	5.50	–	–	–

*FEDIAF [2020a]; DM = dry matter; NFE = nitrogen free extract; A-1 to A-5 = all breeds; L-1 to L-5 = large breeds; S-1 to S-5 = small breeds; MRL = minimum recommended level.
[1]means denoted by different letters differ statistically (P $\leq$ 0.05) (for all columns separately).

[2020a], however the A-4 feed contained almost 2.5 times more protein (43.56 g per 100 g DM) than MRL. There is no specific maximum recommended protein level in feed, however, it should be borne in mind that dietary protein intake may affect kidney function and contribute to disease development. Eating protein in the diet in excess of the recommended minimum level promotes chronic kidney disease by increasing glomerular pressure and hyperfiltration. Moreover, excess protein may worsen the condition of the organism with pre-existing kidney disease [Martin et al. 2005]. On the other hand, a large amount of protein combined with dietary fiber is useful for dogs to reduce body weight [German et al. 2010]. However, long-term consumption of high-protein foods is associated with a negative microbiological and metabolic profile [Gebreselassie and Jewell 2019].

Fats are the main source of energy for both dogs, they provide more than twice as much energy per gram than protein and carbohydrates. Deficiency of fat and fatty acids in the diet leads to body weight loss, weakening of the quality of the hair and skin [Codner and Thatcher 1990]. On the other hand, some diseases require a low-fat diet, e. g. intestinal lymphangiectasia [Melzer and Sellon 2002]. Low-fat diet is also necessary in the treatment of dog obesity. Excessive fat consumption leads to the development of obesity in dogs, and a high-fat diet with inadequate vitamin E content can damage the retina and the lens [Davidson et al. 1998]. Over-the-counter (OTC) dry dog foods contain lipids from plant oils (mainly corn and sunflower), and/or animals (mainly chicken), or a mixture of both. Which fat sources a manufacturer will include in a dog food will depend on several factors, such as essential fatty acid (EFA) content, effect on palatability, susceptibility to oxidation, and market price [Di Donfrancesco et al. 2014, Li et al. 2020]. Depending on the fat source, the feed contains different fatty acid profiles [Pavlisova et al. 2016, Okomoda et al. 2020]. Therefore, it is worth paying attention to this group of ingredients when choosing dog food. In present study tested dog foods mostly had animal fat as their main fat source (see Table 1). For adult dogs, MRL according to the FEDIAF [2020a] is 5.5 g per 100 g DM. All of the tested foods had a fat level higher than MRL (Table 2). Significantly the highest level of crude fat was in the small breed dog food group, where the average was 14.23 g per 100 g DM with a range from 11.43 to 17.84 g per 100 g DM. The lowest values were observed in the group of food for dogs of all breeds, where the average content of crude fat was 13.25 g per 100 g DM. The results were similar to the values obtained as a result of analyzes carried out by Alomar et al. [2006], in which the average fat content was 14.05 g per 100 g DM, ranging from 6.95 to 23.96 g per 100 g DM. In present study, the foods for small breed dogs were the most concentrated in fat and protein, especially in the S-1 food. This food contained lentils as a source of protein, and chicken fat and herring oil as a source of fat. In small breed dogs the metabolism is faster than in large breed dogs, so they should eat food with a higher caloric content. Fat is the main source of energy in the dogs' diet, so its amount was much higher in small-breed dog food than in large-breed dogs.

Crude fiber is part of the dietary fiber. It includes the sum of fibrous substances (cellulose, lignin, hemicellulose, etc.) that are resistant to enzymes of the digestive tract. Current nutritional guidelines do not provide recommended levels of crude fiber in pet food. Crude fiber content recommendations for a dry dog food published by Case et al. [2010] are: no less than 5%. Feeds differed statistically significantly in the level of crude fiber. Significantly more of it was found in group of food for dogs of large breeds, in the range 2.54–5.48 g per 100 g DM, while the average content was 3.40 g per 100 g DM. In the group of food for large breed dogs, the average content of crude fiber was at the level of 3.05 g per 100 g DM, while the range was from 2.26 to 3.49 g per 100 g DM. In the group of food for small breed dogs, the average crude fiber content was 3.39 g per 100 g DM, with the range of 1.64–5.42 g per 100 g DM. Studies showed that high levels of crude fiber content have negative impact, on dogs' food preferences [Alegría-Morán et al. 2019].

Crude ash is required to determine the mineral content of the feed [FEDIAF 2020a]. Too high an ash content in dog food may limit the absorption of other nutrients [Johnson et al. 1998]. Feeds differed statistically significantly in the level of crude fiber. Significantly more was found in group of food for dogs of small breed. In this group of feed, the average content of crude ash was 10.00 g per 100 g DM. Among the feed samples for large breed dogs, the crude ash content was in the range of 5.98–10.00 g per 100 g DM, and the average value was 9.19 g per 100 g DM. The average content of crude ash among feed samples for all breeds was 7.22 g per 100 g DM, in the range of 5.54–10.00 g per 100 g DM.

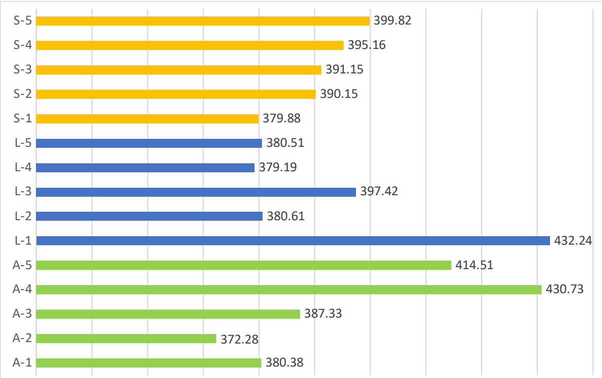
While the dog has a strong preference for protein foods, domestication caused adaptive physiological changes that generated a preference for simple carbohydrates [Bradshaw 2006]. Carbohydrates (NFE, nitrogen-free extracts) are a source of energy for the body, they are used to generate heat. NFE include simple sugars, disaccharides, polysaccharides (starch), and some organic acids. Their excess is stored in the form of glycogen or fat as a reserve material. In most cases, carbohydrates should be the smallest part of a dog' diet. They are not an essential nutrient, but they fulfill many important functions [Hilton 1990]. Low carbohydrate levels in the diet of small and miniature breed young dogs may lead to hypoglycaemia due to their predisposition to be unable to maintain blood glucose levels solely by gluconeogenesis [Vroom and Slappendel 1987]. Excess carbohydrate in the diet over a period of time is not harmful, however, in dogs with diabetes, increasing their intake may lead to hyperglycemia and increase insulin requirements [Elliot et al. 2012]. In the group of food for dogs of all breeds, the highest NFE level (55.40 g per 100 g DM) was found in food A-1. The lowest (32.09 g per 100g DM) level of NFE was detected in feed A-4. The average NFE content in this group was 45.11 g per 100 g DM. In the group of food for small breed dogs, the average NFE content was 40.72 g per 100g DM, in the range of 32.99–48.62 g per 100 g DM. Feeds differed statistically significantly in the level of carbohydrates. Significantly more of NFE was found in group of food for dogs of large breeds. The mean NFE value in this group of feed was 46.25 g per 100 g DM, with the range of 33.88–51.72 g per 100 g DM. The highest NFE level was discovered in L-3, while the lowest – in L-1.

Energy Value

Energy requirements vary considerably between individual dogs, even between animals kept under the same conditions. This wide variation between individual animals can be the consequence of differences in age, breed, body size, body condition, insulation characteristics of skin and hair coat, temperament, health status or activity. It can also be caused by environmental factors such as ambient temperature and housing conditions [Hill and Scott 2004, Bermingham et al. 2014, Alexander et al. 2017]. No-single formula will allow to calculate the energy requirements for all dogs or cats, and every equation only predicts a theoretical average for a specific group of animals [FEDIAF 2020a]. Providing satisfactory feeding recommendations remains thus an ongoing challenge for pet food companies. It has been shown that, in order to optimally cover the daily energy requirements, dogs are able to independently regulate the degree of energy absorption. Energy demand and its expenditure depend on many factors [Harper 1998], for example on the basal metabolism – in small breed dogs the metabolism is faster than in large breed dogs, so they should eat food with a higher caloric content. Significantly the highest metabolizable energy (ME) level was discovered in food for dogs of all breeds, while foods for dogs of small and large breeds did not differ significantly in the average energy concentration (Fig. 1).

Even though small breeds need more energy, research has not confirmed this fact. In the group of food for dogs of small breeds, the highest energy level was detected in

S-5 (399.82 kcal per 100 g DM), while the lowest in S-1 (379.88 kcal per 100 g DM). In the group of food for large breed dogs, the highest energy level was found in L-1 (432.24 kcal per 100 g DM), while L-4 (379.19 kcal per 100 g DM) was the lowest. Among all dog breeds, the range was 372.28–430.73 kcal per 100 g DM. It has been shown that some breeds such as newfoundland dogs and huskies have relatively lower energy requirements, while Great Danes have energy requirements above the average [Burger and Johnson 1991, Kienzle and Rainbird 1991, Meyer and Zentek 1991]. Breed-specific needs probably reflect differences in temperament, resulting in higher or lower activity, as well as variation in stature or insulation capacity of skin and hair coat, which influences the degree of heat loss.



A-1 to A-5 = all breeds; L-1 to L-5 = large breeds; S-1 to S-5 = small breeds

Fig. 1. Metabolizable energy (kcal per 100 g DM) in tested dry dog foods

Dietary Fiber Fractions

The production process of extruded dry food requires materials containing dietary fiber and starch that play a structural role and regulate the course of physical changes during the extrusion process. Starch contributes to both expansion and binding in the final product. Cereal (e.g. wheat, corn, rice, barley, oats and other) and cereal by-products (e.g. flour, bran) are largely used for pet food (see Table 1). Nowadays, more and more attention is paid to nutrients that are difficult for a dog's digestive tract to digest. They are called dietary fiber, which are carbohydrates (polysaccharides) resistant to the action of digestive enzymes and not hydrolyzed in the small intestine of monogastric animals, such as the dog. However, they can ferment in the large intestine. The products of this process support the proper functioning of the intestines [Slavin 2008]. Moreover, the research indicated that fibers have an effect on extruded pet food texture and palatability [Koppel et al. 2015, Venturini et al. 2018, Goi et al. 2020a]. The varied components of dietary fiber have different physical and chemical properties, characterized by their physiological effects on the dog body [de Godoy et al. 2013]. Dietary fiber can be classified according to the ability to dissolve in water (soluble or insoluble form), form a gel consistency (viscous or not) and/or ferment by colon bacteria (fermentable or non-fermentable) [Ha et al. 2000]. It contains both raw insoluble fiber fractions and soluble non-starch polysaccharides. As a result of the use of different definitions and assay methods in research on dietary fiber, considerable problems are encountered when attempting to determine its actual level in food. For this reason, it is crucial to define not only the total level of dietary fiber in the diet, but also its fractional composition, since individual fractions are characterized by diverse action in the dog body. Therefore, in our study we determined the share of NDF, ADF, ADL, and calculated HCEL, and CEL fractions. It should be emphasized that the detergent method determines only the content of the insoluble fraction of dietary fiber. Nutritional guidelines for pet food for cats and dog do not provide minimum recommended levels of dietary fiber and fraction [FEDIAF 2020a], but their evaluation is fundamental when formulating diets. Individual tested foods were characterized by different levels of fiber fractions (Table 3).

The largest part of the fiber was NDF, which consists of the sum of cellulose, hemicellulose and lignin. In contrast, ADF includes cellulose and lignin. In this study significantly the highest level of NDF was discovered in the group of feeds for dogs of all breeds, where the average was 12.85 g per 100 g DM with the range from 10.59 to 16.85 g per 100 g DM. The lowest level of NDF was found in group of feeds for small breed dogs. The average was 12.39 g per 100 g DM, and the range 6.92–16.34 g per 100 g DM. The results obtained in this study were higher than those reported by de-Oliveira et al. [2012] who report the NDF range in dog feed 6.5–11.7 g per 100 g DM. On the other hand, Goi et al. [2020b] obtained results in the study of extruded dog food similar to the presented study (mean 16% NDF).

Lignin is considered insoluble and unfermentable fiber in the large intestine. It lowers cholesterol and triacylglycerol levels due to the ability to permanently bind to bile acids [Ikeda et al. 1989]. Significantly, the lowest ADL value was found in the group of feeds dedicated to all breeds (average 0.94 g per 100 g DM). In this group, the tested foods contained lignin in the range 0.50–1.27 g per 100g DM. The highest content of lignin was discovered in group of foods for large breed dogs. The average was 1.02 g per 100 g DM with the range 0.38–1.53 g per 100 g DM. Our results were lower than in Goi et al. [2020b] results, where the average level of ADL was 1.85 g per 100 g DM, with the range 0.43–4.58 g per 100 g DM.

Only part of the hemicellulose is soluble in water. Its action is indirectly based on the creation of highly

Table 3. Dietary fiber fractions (g per 100 g DM) of the tested dry dog foods

Product	NDF	ADF	ADL	HCEL	CEL
A-1	10.59	5.43	1.10	5.17	4.33
A-2	11.27	5.36	1.17	5.91	4.19
A-3	13.91	4.06	0.66	9.85	3.41
A-4	11.61	5.24	0.50	6.37	4.74
A-5	16.85	5.88	1.27	10.98	4.61
Mean[1]	12.85	5.19[a]	0.94	7.65[b]	4.25[a]
L-1	15.18	5.38	0.81	9.80	4.57
L-2	11.35	4.71	0.97	6.64	3.75
L-3	11.53	8.02	1.53	3.52	6.48
L-4	8.27	2.70	0.38	5.57	2.33
L-5	16.42	8.54	1.43	7.88	7.11
Mean	12.55	5.87[b]	1.02	6.68[a]	4.85[b]
S-1	15.19	7.31	0.90	7.88	6.41
S-2	16.34	11.09	1.81	5.24	9.29
S-3	6.92	3.83	0.59	3.09	3.25
S-4	9.55	3.65	0.80	5.90	2.85
S-5	13.96	5.50	0.95	8.46	4.55
Mean	12.39	6.28[b]	1.01	6.11[a]	5.27[b]

A-1 to A-5 = all breeds; L-1 to L-5 = large breeds; S-1 to S-5 = small breeds; NDF = neutral detergent fiber; ADF = acid detergent fiber; ADL = = acid detergent lignin; HCEL = hemicellulose; CEL = cellulose.
[1] means denoted by different letters differ statistically ($P \leq 0.05$) (for all columns separately).

viscous solutions and impairment of the digestive processes and the absorption of fat and glucose, slowing down the increase in blood sugar [Mimura et al. 2013]. Significantly the lowest HCEL content was found in group of foods for dogs of small breeds. The average was 6.11 g per 100 g DM, with the range from 3.09 to 8.46 g per 100 g DM. The highest HCEL level (average 7.65 g per 100 g DM) was found in group of foods for all breed dogs, where the range was 5.17–10.98 g per 100 g DM.

Cellulose is a source of fiber that is not digested in the small intestine and fermented in the large intestine, and has a moderate water-binding capacity. Accordingly, cellulose is used to improve the quality of the stool, however the effect on the quality may vary depending on the source of the CEL. Faecal dry matter value decreases with increasing length of cellulose fibers. Long-fiber cellulose improves the quality of the stool, in contrast to the short CEL fibers [Wichert et al. 2002]. Cellulose affects the digestibility of nutrients. The CEL by itself has no effect on the apparent fat digestibility, but if cooked starch is present in the diet, the digestibility of the fat may decrease. Cellulose reduces protein and energy digestibility. It also reduces the digestibility of minerals, including potassium, sodium and chlorine [Kienzle et al. 2001]. According to the calculation of the cellulose content in relation to the total, among the analyzed feeds, significantly the lowest cellulose content was found in the group of feeds for dogs of all breeds. The average was 4.25 g per 100 g DM, while the range was from 3.41 to 4.74 g per 100 g DM. The highest level of CEL was discovered in group of foods for dogs of small breeds, where the average was 5.27 g per 100 g DM, and the range was from 2.85 to 9.29 g per 100 g DM.

The consequence resulting from the participation of individual fractions of dietary fiber in the method of fiber determination with the detergent method analyzed in the feeds, was the fact that in feeds with a low hemicellulose content, cellulose was at a high level. This relationship was also observed in the other direction – feeds containing a small amount of cellulose were characterized by a high content of hemicellulose. Whole grains are the main component in the A-3 feed, which may explain the lowest cellulose content among the feeds tested and the highest hemicellulose. Unfortunately, the producer does not specify the species of the cereals used, but considering that this feed has the highest percentage of HCEL in the NDF fraction, this may suggest that the producer may have used barley and/or oats. The grains of these cereal species are characterized by a high proportion of the soluble dietary fiber fraction. Soluble beta-glucans dominate among the components of hemicelluloses in these cereals [Biel and Jacyno 2014]. Another feed with a low content of CEL and a high level of HCEL was the A-5 feed, in which, with a low level of bison meat and animal meals, sweet potatoes, peas and potatoes were used, i. e. ingredients providing mainly soluble dietary fiber (including hemicellulose, pectin). According to the producer's declaration, L-4 feed consists mainly of corn, the high content of which is responsible for the low level of cellulose and high hemicellulose [Twomey et al. 2003]. L-3 feed was characterized by the lowest HCEL content and at the same time the highest CEL content. The producer did not declare the exact names of the species of the components used, therefore it cannot be clearly stated which component is the source of such a high level of cellulose in the feed. Another food with a low hemicellulose content and a high cellulose content was the S-2 food. Such results may be due to wheat bran and whole wheat added to the feed.

Each fraction of the dietary fiber in the optimal amount has a health-promoting effect on the functioning of the body [Graham et al. 2002], it should be borne in mind that cellulose and hemicellulose – which are non-starch carbohydrates (NSPs) – may excessively limit the absorption of nutrients contained in food for the dog. Despite dogs being carnivores, they can benefit from fiber consumption for either weight management and gut health [Donadelli and Aldrich 2019]. The source of the dietary fiber is also important. Dog diets do not recommend high amounts of carbohydrate from sources such as wheat, barley, and oats that are high in NSP [Guilford 1994]. The studies of Inal et al. [2017] showing barley as an alternative to typical rice in dog food. Barley has one of the lowest glycemic indices of all cereal grains. Studies showed that barley does not disrupt stool quality indicate that barley can be used effectively in dog food. Dry matter and crude protein digestibility of food with rice and barley food were similar.

CONCLUSIONS

This study highlights non-compliance of popular pet foods with current EU guidelines. If fed exclusively and over an extended period, a number of these pet foods could impact the general health of companion animals. Dietary fiber fractions, despite the fact that they are an extremely important element in the nutrition of both dogs, are rarely discussed. When choosing a food, always pay attention to the label and carefully analyze the component composition of the product. but it is necessary to not ignore the nutrient assessment, because the food that dogs receive for a longer period of their lives should be complete and balanced, i. e. providing all the necessary nutrients in the right amounts and proportions. It is worth choosing feeds, the manufacturer of which declares the component composition according to the names of the raw materials, thanks to which you know exactly what species was used to produce the feed. While the addition of carbohydrates has beneficial properties, many manufacturers use too much of it. Keep in mind that the dog is a relative carnivore and most of its diet should be meat products. It is necessary to select the appropriate food according to the animal's needs, its physiological condition, age and breed size. The domestic dog is a very diverse species – small breeds require different food than large breeds. The key factor here is not only the appropriate size of the granules to facilitate food intake, but also its basic composition and the presence of the desired additives.

All analyzed feeds met the FEDIAF [2020a] minimum recommended levels of protein and fat. Individual tested foods were characterized by different levels of dietary fiber fractions (NDF, ADF, HCEL, CEL). The group of foods for small breed dogs was characterized by the lowest mean of ME (391.23 kcal per 100 g DM). A higher level of ME (393.99 kcal per 100 g DM) was observed in the group of foods for dogs of large breeds, and the highest (397.05 kcal per 100 g DM) – in the group of foods for dogs of all breeds.

The results obtained support the need for more frequent, regular, and more accurate analyzes of pet food. The information provided on the dog food label should be more comprehensive and include detailed information on the content of all essential minerals, as pet owners have the right to know what they are feeding their pets. The presented study also showed that nutrient levels should only be verified on the basis of nutritional guidelines.

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OSZACOWANIE ZAWARTOŚCI GŁÓWNYCH SKŁADNIKÓW ODŻYWCZYCH W SUCHEJ KARMIE DLA PSÓW I ICH ZGODNOŚĆ Z WYTYCZNYMI ŻYWIENIOWYMI

STRESZCZENIE

Celem pracy była ocena ekstrudowanej pełnoporcjowej suchej karmy dla psów dorosłych w oparciu o wartość odżywczą z uwzględnieniem aktualnych wytycznych żywieniowych dla psów, frakcji włókna pokarmowego oraz podziału na wielkość rasy. Karmy dla psów poddano analizom chemicznym w celu określenia zawartości podstawowych składników odżywczych oraz frakcji włókna pokarmowego oraz wyliczenia wartości energetycznej (EM). Materiał do badań stanowiło 15 karm bytowych dla psów dorosłych (5 dla psów ras dużych, 5 dla psów ras małych i 5 dla psów wszystkich ras). Wszystkie analizowane karmy spełniały minimalne zalecane poziomy dla białka i tłuszczu. Poszczególne badane karmy charakteryzowały się statystycznie różnym poziomem frakcji włókna pokarmowego (ADF, HCEL, CEL). Grupa karm dla psów ras małych charakteryzowała się najniższą średnią EM (391,23 kcal na 100 g SM). Wyższy poziom EM (393,99 kcal na 100 g SM) zaobserwowano w grupie karm dla psów ras dużych, a najwyższy (397,05 kcal na 100 g SM) – w grupie karm dla psów wszystkich ras.

Słowa kluczowe: wielkość rasy, karma pełnoporcjowa, wartość energetyczna, ekstrudowana karma dla psów, frakcje włókna pokarmowego, zapewnienie jakości

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