DOI: 10.21005/AAPZ2024.69.1.5

FOLIA POMERANAE UNIVERSITATIS TECHNOLOGIAE STETINENSIS
Folia Pomer. Univ. Technol. Stetin., Agric., Aliment., Pisc., Zootech. 2024, 370(69)1, 46–60

Review article

Received 28 Dec 2023
Revised 5 Feb 2024
Accepted 8 Feb 2024

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FATTY ACID PROFILES AND FAT CONTENTS IN FISH, MODIFICATION METHODS AND POTENTIAL USES IN THE NUTRITION OF DOGS AND CATS

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Abstract. Fish are rich in high-quality protein. Additionally, they are known for their high content of polyunsaturated fatty acids such as EPA and DHA. This review aims to provide an overview of the lipid fraction of selected fish species, exploring methods of manipulating fatty acid content and discovering the resulting health benefits for dogs and cats. The article discusses innovative methods used to manipulate fatty acid content in fish, including nutritional strategies, selective breeding and new technologies. Based on the current scientific literature, the article synthesizes knowledge on the impact of these manipulation methods on the nutritional quality of fish. Additionally, literature data were presented indicating the positive aspects of including fish in the diet of dogs and cats. EPA and DHA are responsible for a number of health benefits, including supporting the circulatory system, cognitive functions and the learning process, an element of diet therapy in the treatment of cancer, and alleviating pain associated with degenerative joint diseases.

Key words: cats nutrition, dogs nutrition, fatty acids, freshwater fish, health benefits, n-3, nutritional guidelines, nutritional value, PUFA, saltwater fish.

INTRODUCTION

Fish, as a food group, is controversial among Polish consumers. The health benefits of fish and fish products are the most important factor influencing their purchase by consumers. Other important factors are the taste of fish and the desire to diversify the diet. Unfortunately, there is still a large group of consumers who eat fish too rarely. Poles who never buy fish or fish products most often point to their high price and characteristic taste as the reason for that. The low level of consumer knowledge about the nutritional value of fish and fish products is very disturbing. This has consequences not only in people's diets, but also in the diets of their pets. It is often the case that caregivers do not give animals raw materials that they would not like to eat themselves. The intensification of the phenomenon of the so-called "humanization" of the offer addressed to dogs and cats caregivers has been widely

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noticed and commented on in the scientific literature only for several years (van Herwijnen et al. 2020; van Herwijnen 2021).

Fish contain 16-20% of complete and well-digestible protein. They are also a source of B vitamins, calcium, potassium, magnesium, iron and zinc. Sea fish are also a source of iodine. In addition, fatty fish provide retinol and vitamin D. The fat content in fish varies, ranging from a few to even 20% and more. For this reason, there are lean fish (fat content up to 5%), including: cod, flounder, pollock, tuna, sole and most freshwater fish: zander, perch, carp, tilapia, pangasius and fatty fish (content up to 20%), such as: salmon, mackerel, herring, halibut and freshwater: rainbow trout. Fish fat contains long-chain polyunsaturated fatty acids (LC-PUFA) (eicosapentaenoic acids, EPA C20:5 n-3 and docosahexaenoic acid, DHA C22:6 n-3) (Kaliniak et al. 2015; Sąsiadek et al. 2018; Zhang et al. 2020). These essential nutrients, specifically n-3 fatty acids (FAs), play a crucial role in maintaining optimal health and are recognized for their diverse benefits (Tokarczyk et al. 2017).

Eating fish meat (especially fatty sea fish) containing n-3 fatty acids prevents the formation of blood clots in blood vessels. Numerous studies have investigated the association between fish consumption and n-3 fatty acids intake, highlighting the positive impact on cardiovascular health, cognitive function, and other aspects of well-being (Michalska and Nowachowicz 2009; Aglago et al. 2020; Lorensia et al. 2021). Fish and fish products constitute a group of food products with very high nutritional value. The main advantage of fish meat is the high content of protein characterized by very high digestibility (93–97%), which results, among others, from the low content of connective tissue. Moreover, as shown by Jiang et al. (2022), cooking increases protein digestibility (1.60–8.28%), and steaming was indicated as the best method of cooking fish to improve protein digestibility.

Fish are an important source of protein and n-3 acids. Depending on the region, different species of fish are eaten around the world. Fatty sea fish are especially recommended due to the high content of PUFA, from the n-3 family (Bonilla-Méndez et al. 2018).

For the above reasons, fish are also eagerly used in pet food production, but it should be borne in mind that these feed materials differ significantly in terms of nutritional value, protein and fat content and their quality. This is influenced by a number of factors: fish species, gender, type of raw material, but also the place and period of fishing, housing system and nutrition (Kaliniak et al. 2015; Sąsiadek et al. 2018; Zhang et al. 2020).

With the above in mind, it is worth answering the question whether fish, provide large amounts of valuable fatty acids, but also harmful substances, can be a healthy and appropriate element in the diet of dogs and cats? The aim of the review article is to attempt to answer the question of which species of fish should be included in the diet of dogs and cats and why, as well as to verify views on the quality of fish fat and methods of modifying the fatty acid content in this valuable raw material.

NUTRITIONAL VALUE OF FISH

Protein

One of the primary nutritional attributes that elevates fish to a prominent status in dietary considerations is its high-quality protein content. Fish protein is considered complete, containing all the essential amino acids that the body cannot produce on its own or the production is too low. This makes fish an excellent source of protein in the diet of both dog and cat. The digestibility and bioavailability of fish protein further enhance its nutritional value, making it an ideal choice for those seeking to meet their protein requirements efficiently (Mohanty et al. 2014). The protein content in fish meat ranges from 13.80 to 22.56 g/100 g fish/whole body (Table 1) and is of higher quality based on its amino acid composition compared to other frequently used protein components in commercial foods. Generally based on literature data, it can be concluded that saltwater fish, especially anchovies (22.56 g/100 g) are richer in terms of protein content compared to freshwater fish, e.g. roach has a protein content of 14.38 g/100 g (Table 1).

Table 1. Major nutrients (g/100 g) in selected fish species

Item	Moisture	Protein	Fat	Ash	Reference
Saltwater fish:					
Anchovy (*Engraulis encrasicolus* L.)	74.90	22.56	2.24	1.28	Feng et al. (2012)
Cod (*Gadus morhua* L.)	78.46	21.07	0.13	1.37	Walker and Berlinsky (2011)
Haddock (*Melanogrammus aeglefinus* L.)	77.50	13.80	0.95	2.20	Nanton et al. (2001)
Halibut (*Hippoglossus hippoglossus* L.)	71.20	16.20	10.50	2.20	Berge et al. (2023)
Herring (*Clupea harengus* L.)	76.73	19.94	7.80	1.55	Aro et al. (2000)
Mackerel (*Scomber scombrus* L.)	69.70	21.46	8.23	1.25	Feng et al. (2012)
Salmon (*Salmo salar* L.)	70.60	17.80	9.50	2.10	Bendiksen et al. (2003)
Sprat (*Sprattus sprattus* L.)	76.90	17.50	4.30	1.30	Merdzhanova et al. (2018)
Freshwater fish:					
Bream (*Abramis brama* L.)	77.37	18.00	3.63	1.00	Żmijewski et al. (2006)
Carp (*Cyprinus carpio* L.)	78.00	16.80	4.00	1.10	Ljubojević et al. (2015)
Perch (*Perca fluviatilis* L.)	79.63	16.55	0.80	1.72	Linhartová et al. (2018)
Pike (*Esox lucius* L.)	77.61	19.21	2.29	1.30	Hajisafarali et al. (2015)
Roach (*Rutilus rutilus* L.)	78.30	14.38	3.38	2.49	Chitsaz et al. (2016)
Trout (*Oncorhynchus mykiss* W.)	73.80	19.40	6.50	1.40	Morris et al. (2005)

Despite its nutritional value, when using fish protein in the diet of dogs and cats, caution should be exercised in certain cases due to the possibility of allergies. One of the most frequently diagnosed allergic skin diseases in dogs and cats is food allergy. It is the second or third – after atopic dermatitis and possibly flea allergy dermatitis – skin disease caused by hypersensitivity. Its cases account for approximately 1 to 5% of all skin diseases in dogs and approximately 23% of cases of non-seasonal allergic diseases in dogs (Szczepanik and Pomorska 2005; Stilwell 2019). Dogs are occasionally allergic to fish protein. Beef (36%), dairy products (28%), wheat (15%), eggs (10%), and chicken (9.6%) are responsible for the majority of allergic reactions in dogs (Verlinden et al. 2006). In cats, the development of allergies is mainly caused by commercial food (24.8%), beef (20%), dairy products (14.6%), fish are in fourth place (13%).

Fat and fatty acids

Living organisms need energy to fuel all body functions. Fat provides essential fatty acids, fat-soluble vitamins and almost 3 times more energy than protein and carbohydrates. In the case of fat content, a similar relationship can be observed as in the case of protein. Sea fish turn out to be richer in this nutrient. A good example is halibut, which is characterized by a particularly high fat content (10.50 g/100 g). In the case of freshwater fish, perch (*Perca fluviatilis* L.) contains the least fat among the collected literature data (0.80 g/100 g) (Table 1).

European nutritional guidelines (FEDIAF 2021) provide minimum recommended level (MRL) of fatty acids only for arachidonic acid (AA C20:4 n-6) and linoleic acid (LA C18:2 n-6) for adult cats and only for LA for adult dogs. Only for growing and in reproduction animals, nutritional guidelines provide recommended contents of other fatty acids (Table 2).

Table 2. Recommended fatty acids levels (in 100 g dry matter) for complete dog and cat food (FEDIAF 2021)

Item	Unit	Dogs		Cats	
		adult*	growth/ reproduction	adult**	growth/ reproduction
n-6:					
LA	g	1.32	1.30	0.50	0.50
AA	mg		30.00	6.00	20.00
n-3:					
ALA	g	NR	0.80	NR	0.02
EPA+DHA	g	NR	0.05	NR	0.01

* Based on maintenance energy requirements/MER of 110 kcal/kg body weight/BW$^{0.75}$. ** Based on maintenance energy requirements/MER of 100 kcal/kg body weight/BW$^{0.75}$. NR – no recommendation.

Unlike certain red meats, fish tends to be lower in saturated fatty acids (SFA) (Fernandes et al. 2014). The incorporation of fish into diet can contribute to a healthier lipid profile, reducing the risk of cardiovascular diseases associated with high saturated fat intake. This makes fish a favorable choice for pets that need to control their cholesterol levels and maintain a heart-healthy lifestyle (de Albuquerque et al. 2021).

The most celebrated aspect of fish nutrition is its abundance of high-quality fat, especially in the context of n-3 fatty acids, specifically EPA and DHA. These essential fatty acids play a pivotal role in supporting cardiovascular health, reducing inflammation, and promoting optimal brain function. The unique composition of n-3 fatty acids in fish contributes to a decreased risk of heart disease, lower blood pressure, and improved cognitive function (Billman et al. 1999; McLennan 2001; Zicker et al. 2012; Hadley et al. 2017).

Saltwater fish inhabit oceans and seas, environments abundant in marine life. These fish often feed on a diverse diet of algae, plankton, and smaller fish, which are themselves rich sources of n-3 fatty acids, especially EPA and DHA. In contrast, freshwater ecosystems may not provide the same abundance of n-3-rich organisms. Freshwater fish often have diets that include insects, plants, and other organisms with lower n-3 content (Galloway and Winder 2015; Colombo et al. 2017; Gladyshev et al. 2018).

Freshwater fish contain much less lipids than marine species (Table 1). This has a direct impact on the texture of their meat, which is very tender. The lower lipid content translates into faster digestion of freshwater fish, but it is worth remembering that they contain valuable n-3 acids. The undisputed leaders when it comes to the content of n-3 fatty acids are indeed fatty sea fish such as mackerel, anchovies (Table 3). The PUFA content in their fat may even exceed 45% of the sum of fatty acids (Öksuz et al. 2009; Zeng et al. 2010; Guizani and Moujahed 2015). However, based on literature data, it can be concluded that the best source of PUFA is cod (58.70% of the sum of fatty acids) (Zeng et al. 2010). Among freshwater fish, the best in this respect are roach, perch and pike, the fat of which also contains about 50% PUFA, including almost 30% fatty acids from the n-3 family. In carp fat, the sum of UFA is approximately 76.71% of the sum of fatty acids (Table 4).

Table 3. Fatty acids composition (% total FA) and quality indicators of selected species of saltwater fish

Item	Salmon	Herring	Mackerel	Sprat	Anchovy	Halibut	Haddock	Cod
C16:0	9.70	17.12	21.76	26.18	22.13	14.60	18.50	17.70
C18:1 n-9 trans	39.00	23.13	12.23	1.13	8.79	13.00	11.90	9.00
C18:2 n-6	15.00	4.88	1.46	1.82	1.47	3.60	5.80	5.10
C20:4 n-6	0.30	1.21	2.37	2.45	2.34	1.00	2.20	2.60
C18:3 n-3	3.90	1.26	0.73	2.22	0.39	0.90	0.30	0.40
C20:5 n-3	1.80	4.49	7.80	1.32	5.65	10.60	11.50	13.90
C22:6 n-3	4.80	8.26	35.66	6.76	33.40	13.20	25.70	31.00
SFA	14.80	23.41	33.11	47.44	37.96	23.50	24.90	23.90
MUFA	53.90	39.01	20.29	25.83	14.31	34.10	19.30	15.30
PUFA	31.30	33.93	45.94	26.73	47.70	40.80	53.40	58.70
UFA/SFA	5.76	3.12	2.00	1.27	1.63	3.19	2.81	3.10
n-6/n-3	1.48	0.37	0.09	2.64	0.11	0.20	0.24	0.19
Unidentified FA	0.00	3.66	0.66	0.00	0.03	1.60	2.40	2.10
Reference	Ruyter et al. (2022)	Aro et al. (2000)	Guizani and Moujahed (2015)	Stancheva et al. (2010)	Öksuz et al. (2009)	Zeng et al. (2010)	Zeng et al. (2010)	Zeng et al. (2010)

Table 4. Fatty acids composition (% total FA) and quality indicators of selected species of freshwater fish

Item	Bream	Trout	Carp	Roach	Perch	Pike
C14:0	2.28	3.33	1.35	0.82	0.89	1.04
C16:0	18.80	15.61	19.06	20.34	20.53	20.56
C18:1 n-9 trans	17.51	31.89	32.37	8.67	6.88	7.68
C18:2 n-6	2.66	10.97	32.54	4.08	2.74	2.41
C20:4 n-6	3.55	0.00	0.45	8.10	7.71	6.22
C18:3 n-3	1.15	2.98	4.96	1.82	0.91	2.14
C20:5 n-3	0.28	3.73	0.38	12.71	8.07	8.74
C22:6 n-3	9.54	10.39	2.34	22.04	29.65	32.51
SFA	27.40	22.17	27.26	29.61	27.97	29.01
MUFA	37.67	43.50	35.04	13.79	13.68	10.39
PUFA	23.08	34.33	41.67	51.82	51.96	55.02
UFA/SFA	2.22	3.51	2.81	2.22	2.35	2.25
n-6/n-3	0.45	0.63	4.43	0.36	0.30	0.22
Unidentified FA	11.85	0.00	0.00	4.78	6.39	5.58
Reference	Lenas et al. (2011)	Trbović et al. (2012)	Zhou et al. (2018)	Bazarsadueva et al. (2021)	Bazarsadueva et al. (2021)	Bazarsadueva et al. (2021)

Freshwater fish are lean and medium-fat, therefore the content of n-3 fatty acids in the fresh flesh of fish is usually lower than in fatty sea fish. Therefore, to provide the recommended daily dose of EPA+DHA (Table 2) for the prevention of heart diseases, caregivers should provide pets a much larger portion of lean freshwater fish than fatty marine fish.

Other nutrients

What is more, fish are a rich source of various vitamins and minerals. Notably, they are an excellent source of vitamin D, which is crucial for bone health, immune function, and overall well-being. Additionally, fish provide essential minerals such as iodine, selenium, zinc, and each of them plays a vital role in maintaining a balanced and functional physiological system (Bourre and Paquotte 2008; Balami et al. 2019).

FACTORS AFFECTING THE QUALITY OF FAT AND FATTY ACIDS

The manipulation of fatty acid content in fish has become a subject of increasing interest, as researchers and aquaculture experts explore innovative strategies to enhance the nutritional profile of these aquatic species. It applies especially to fatty acids, which play a pivotal role in human health, known for their cardiovascular and cognitive benefits (Ibrahim et al. 2022; Carr et al. 2023).

One primary way for manipulating fatty acid content in fish involves controlling their diets. Fish acquire fatty acids from the food they consume, and by adjusting the composition of their feed, breeders can influence the type and amount of fatty acids deposited in fish tissues. Incorporating specific nutrients into the diet, such as algae or fish oil rich in n-3 fatty acids, has been a common strategy to boost the health-promoting lipid content in farmed fish (Qiu et al. 2017; Qin et al. 2022).

The fatty acids composition of fish is affected by many factors such as species, capture area, temperature and fishing season; however, it is believed that the dietary fatty acids in fish have a direct influence on its FAs composition (Lei et al. 2013; Zakęś et al. 2016a, 2016b). Marine fish have a limited ability to express Δ6/Δ5 desaturases and elongases of long-chain fatty acids, which limits their ability to produce LC-PUFA from their precursor. Therefore, in addition to EPA and DHA, an appropriate amount of arachidonic acid (AA) should be included in the diet to optimize the feed efficiency of growing fish (Magalhães et al. 2020).

An example of methods for modifying the nutritional value of fish using plant raw materials is the study of Alhazzaa et al. (2013). In that study, ectothermic fish were fed a diet rich in LC-PUFA from fish oil, *Echium plantagineum* oil or rapeseed oil deficient in LC-PUFA. After 5 weeks at an optimal temperature of 30°C, when growth rates were comparable between diets, the water temperature was lowered to 20°C for 1 week for half of the animals and maintained at 30°C for the other half. These studies showed that lowering temperature increased the content of LC-PUFA in the liver and skeletal muscle of fish fed *Echium plantagineum* oil compared to rapeseed oil, while LC-PUFA stores in the diet of fish fed fish oil were rapidly depleted after a week of exposure to suboptimal temperature. Rapid exposure of an ectothermic vertebrate to lower and suboptimal temperature resulted in significant modulation of fatty acid composition.

In a study by Ruyter et al. (2022) in the salmon (*Salmo salar*) diet, conventional rapeseed oil was replaced by DHA-enriched rapeseed oil (DHA-CA) gradually in amounts of 0%, 25%, 50% and 100%. Seawater-reared salmon were observed to increase from approximately 465 g to 1.5 kg for all diet variants. Whole body fatty acid retention was high, with greater retention of α-linolenic acid (ALA) and EPA in the groups containing higher DHA-CA oil content. With an increased content of DHA-CA in the diet, a significant increase in lipid mediators with anti-inflammatory and pro-resolving properties was also observed. The inclusion of DHA-CA in the fish diet also had a positive effect on salmon muscle and skin color, increasing fillet quality, which may have a positive effect for consumers (Ruyter et al. 2022).

Trbović et al. (2012) analyzed the effects of three commercially available pelleted diets on the fatty acid profile in rainbow trout (*Oncorhynchus mykiss*) production. Commercial rainbow trout diets contained significantly varying amounts of SFA ranging from 21.02 to 38.50%. Significant differences were found between the diets in the proportions of MUFA (29.56–45.21%) and PUFA (31.95–36.43%). The obtained results indicate that the fatty acid profile of fish reflects the composition of fatty acids in the fish diet, with some differences that indicate that the incorporation of fatty acids into fish tissue is subject to certain metabolic effects.

Zhou et al. (2018) analyzed the effect of replacing fish meal (FM) in the diet with *Hermetia illucens* larvae meal (BSFLM) on the growth and body composition of carp (*Cyprinus carpio*). After 56 days of diet, the growth and body composition of the fish were determined. In this study, replacing fish meal with BSFLM larvae meal had no effect on the growth, biological parameters, proximate composition, amino acid composition and biochemical parameters of carp serum. This study shows that up to 140 g/kg BSFLM (100% FM replacement) can be incorporated into the carp diet without adversely affecting growth, while reducing the n-3 highly unsaturated fatty acid (HUFA) composition in the fish body, suggesting that BSFLM can be used after enrichment with n-3 HUFA nutrients to achieve an active effect on the quality of fish.

Starvation has long been used as a means of manipulation of body compositions and fillet quality, in particular lipid composition of fish. On the other hand, the effects of dietary lipid level on fish have been well-studied, confirming that the lipid content in fish could be increased by higher dietary lipid levels (Xu et al. 2022).

Selective breeding represents another powerful tool in altering the fatty acid composition of fish. By breeding individuals with desirable fatty acid profiles, breeders aim to develop strains of fish that naturally possess higher levels of n-3 fatty acids or other beneficial nutrients. This method holds promise for creating fish varieties with enhanced nutritional value without relying solely on external dietary manipulations (Horn et al. 2022; Zhang et al. 2023).

The growth of aquaculture has opened avenues for refining the fatty acid content of fish. Controlled environments allow for the optimization of feeding regimens and the use of alternative ingredients in fish feeds. Sustainable and well-designed aquaculture practices can potentially produce fish with healthier lipid profiles while minimizing the environmental impact of fish farming (Zlaugotne et al. 2022; Nathanailides et al. 2023).

Emerging technologies, such as genetic modification, offer new possibilities for manipulating the fatty acid content in fish. Researchers are exploring genetic engineering to enhance the synthesis of specific fatty acids or to introduce genes responsible for producing n-3 fatty acids. While these technologies are in their infancy and raise ethical and environmental concerns, they exemplify the extent of human ingenuity in reshaping the nutritional landscape of fish (Wheeler et al. 2013; Khan et al. 2017; Sprague et al. 2017).

THE HEALTH PROPERTIES OF FATTY ACIDS OF FISH

In the nutrition of companion animals, it is necessary to supply EPA and DHA with the diet because the activity of the Δ5-desaturase and Δ6-desaturase enzymes is limited, which leads to insufficient conversion of the precursors to EPA and DHA (Lenox 2016). Docosahexaenoic acid plays an important role in the development and maintenance of brain function. Rodrigues et al. (2023) assessed the effect of fish oil containing DHA concentrate on cognitive functions in young dogs. It has been found that supplementing fish oil containing DHA concentrate in puppies can positively affect their learning ability. At the same time, it strengthens cognitive functions. Moreover, DHA supplementation promoted an increase in EPA and DHA concentrations in serum without changing the total antioxidant capacity of the body.

DHA is the main component of brain gray matter. In the case of elderly dogs, it has been shown that the cognitive decline associated with aging can be alleviated by dietary supplementation with a nutrient mixture consisting of, among others; from fish oil. Long-term supplementation with sources of EPA and DHA may have cognitive-enhancing effects and support the use of nutritional strategies to target risk factors associated with brain aging as an intervention to delay cognitive aging (Pan et al. 2018). In the study by Hadley et al. (2017), older beagle dogs experienced in performing delayed and mismatched visuospatial working memory tasks were fed a DHA-enriched diet for 25 weeks. Initial learning of visual and variable contrast discrimination protocols, but not long-term recall of the simultaneous discrimination task, was observed in animals. The results of this study indicate that sources of DHA may be used to support brain function in a canine model of aging. Cognitive dysfunction syndrome affects not only dogs, but also cats. Pan et al. (2012) supplemented middle-aged and elderly cats with a mixture of nutrients (antioxidants, arginine, B vitamins and fish oil). Cats fed the test diet showed significantly better results in learning and acquiring spatial memory. The results support the hypothesis that brain function in middle-aged and older cats can be improved with a nutritional mix selected to minimize or eliminate risk factors associated with brain aging and dementia.

Ravić et al. (2022) analyzed the potential benefits of feeding fish-based foods rich in n-3 acids to working dogs. Feeding this type of food reduced the levels of blood glucose, total cholesterol and LDL cholesterol. Importantly, correlations of phospholipid fatty acids composition between plasma and erythrocytes demonstrated that both plasma and erythrocytes can serve as markers of EPA and DHA intake levels in dogs. Moreover, feeding a fish-based diet resulted in a significant reduction in lipid peroxidation markers. Enriching dogs' diets with marine fish may improve oxidative status and the status of bioactive lipids such as membrane phospholipids and fatty acids. It was found, that fish oils that are rich in EPA and DHA lower levels of blood triglycerides in dogs (Jackson et al. 2023).

Reducing dietary saturated fatty acids and increasing polyunsaturated ones, especially from fish, have long been known to improve vascular health and may improve measures of arterial stiffness. Fish oil has also been shown to be effective in dogs suffering from osteoarthritis. The combination of fish oil with other chondroprosthetics, such as hyaluronic acid, seems to be of particular importance (Webber et al. 2020; Kampa et al. 2023).

Park et al. (2011) analyzed modulatory effects of PUFA on inflammation and immune response in domestic cats. It was found, that fish and linseed oil may reduce skin inflammatory reactions in cats, but linseed oil appears to be less immunosuppressive than fish oil.

Freeman et al. (1998) attempted to characterize nutritional and cytokine changes in dogs with heart failure and the ability of fish oil to reduce cytokine levels and improve clinical outcomes. The data show that heart failure in dogs is associated with cachexia, changes in fatty acids and reduced caloric intake. Fish oil supplementation reduced IL-1 concentrations and improved cachexia. Additionally, IL-1 reduction predicted survival, suggesting that anti-cytokine strategies may be beneficial for patients with heart failure.

It is known that fish oil, due to its PUFA richness, has an effect on mitigating the growth and progression of cancer. Ogilvie et al. (2000) analyzed the effect of an EPA and DHA enriched diet on the remission and survival of dogs diagnosed with lymphoma. These dogs were already receiving chemotherapy as their main therapy, and the addition of the experimental diet allowed for longer disease-free periods and survival times compared to those obtained with a placebo diet. Although this study had some concerns due to a lack of clear information about patient selection and the randomization process, the identified association between high serum EPA and DHA levels and improved health supports the idea that dogs diagnosed with lymphoma may benefit from benefits of LC-PUFA supplementation.

Importantly, not only the content of fatty acids, but also their proportions (Table 3 and 4) are important for the health of the dog's and cat's body. As the literature on the subject indicates, an excess of n-6 fatty acids can pose a danger to the proper utilization of n-3 fatty acids. An explanation can be the fact that FAs from the n-3 and n-6 families compete for the same enzymes required to convert these acids into a usable form (Schmitz and Ecker 2008). It was shown that animals fed food with an n-6/n-3 ratio of 5 : 1 and 10 : 1 produced fewer inflammatory mediators than those fed food rich in n-6 and a fatty acid ratio of 100 : 1 (Avramovic et al. 2012).

CONCLUSION

A review of the literature on the subject showed that fish are an important component of the diet of dogs and cats due to their high nutritional value, making them the basis of a well-composed and health-conscious diet. From high-quality protein to a wealth of n-3 fatty acids and a range of vitamins and minerals, fish offers a holistic approach to nourishing the body. In particular, they are an important and difficult to replace source of fat with the desired fatty acid profile. EPA and DHA are particularly important fatty acids in the nutrition of dogs and cats. Fish are an exceptional source, especially sea fish. The composition of fatty acids can be modified in many ways, and science is still developing in this direction to provide not only humans, but also our animals with feed materials of high nutritional value. An optimal profile of fatty acids, with particular emphasis on LC-PUFA, is desirable in the diet of companion animals due to their health-promoting properties, in particular improving the functioning of the circulatory system or maintaining cognitive abilities in aging animals.

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PROFIL KWASÓW TŁUSZCZOWYCH I ZAWARTOŚĆ TŁUSZCZU W RYBACH, METODY MODYFIKACJI I MOŻLIWOŚCI WYKORZYSTANIA W ŻYWIENIU PSÓW I KOTÓW

Streszczenie. Ryby bogate są w wysokiej jakości białko. Ponadto są znane z dużej zawartości wielonienasyconych kwasów tłuszczowych, takich jak EPA i DHA. Celem niniejszej pracy przeglądowej była charakterystyka frakcji lipidowej wybranych gatunków ryb, ukazanie metod modyfikacji zawartości kwasów tłuszczowych i wynikających z tego właściwości zdrowotnych dla psów i kotów. W artykule omówiono innowacyjne metody stosowane do manipulowania zawartością kwasów tłuszczowych w rybach, obejmujące strategie żywieniowe, hodowlę selektywną i nowe technologie. Opierając się na aktualnych doniesieniach naukowych, dokonano syntezy wiedzy na temat wpływu tych metod manipulacji na wartość odżywczą ryb. Ponadto przedstawiono dane literaturowe wskazujące na pozytywne aspekty wynikające z włączenia ryb do diety psów i kotów. Kwasy EPA i DHA zapewniają wiele korzyści zdrowotnych, w tym wspierają układ krążenia, funkcje poznawcze i proces uczenia się, są elementem dietoterapii w leczeniu chorób nowotworowych, a także łagodzą ból związany z chorobami zwyrodnieniowymi stawów.

Słowa kluczowe: żywienie kotów, żywienie psów, kwasy tłuszczowe, ryby słodkowodne, korzyści zdrowotne, n-3, wytyczne żywieniowe, wartość odżywcza, PUFA, ryby morskie.