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STUDY ON THE NUTRITIVE VALUE OF RAW FISH OILS

Zygmunt Usydus[1], Lucyna Polak-Juszczak[1], Zbigniew Dobrzański[2], Małgorzata Malesa-Ciećwierz[1]

[1]Sea Fisheries Institute of Gdynia; [2]Department of Animal Hygiene and Ichtiology, Wroclaw University of Environmental and Life Sciences

Key words: fish oil, fatty acids, vitamins soluble in fats, micro and macroelements

The aim of the work was chemical assessment of raw fish oils obtained from technological waste remaining from processing of different fish species (herring, sprat, Norwegian salmon, trout) from the point of view of their feeding value for farm animals. Composition of fatty acids has been determined with special consideration of polyunsaturated ω-3 (PUFA n-3) ones. Additionally, vitamins soluble in fats (A, E, D_3) and essential macro- and chosen microelements contents have been assessed. It was found that fish oils were characterised by very beneficial fatty acids composition, significant content of D_3 and E vitamins, as well as of phosphorus, calcium, sodium, potassium and iron.

INTRODUCTION

In recent years, the use of fish oils obtained from whole fish and technological waste products, destined for farm animal feeding has been steadily increasing [Bryhni *et al*., 2002; Dobrzański *et al*., 2002a; Korniewicz *et al*., 2002; Usydus, 2005]. This is due to the fact that fish oils are a valuable ingredient of feed mixtures and concentrates, fed both to monogastric animals and ruminants. Fish oils are a valuable source of energy, especially because they contain polyunsaturated fatty acids (PUFA), three of which are of particular physiological importance, since to some extent, they are synthesized in animal and also human body. What distinguishes fish oils from other types of oils (of animal or plant origin), is their content of long-chain polyunsaturated fatty acids (L-PUFA), such as: docosahexaenoic (22:6, n-3, DHA), eicosapentaenic (20:5, n-3, EPA) and docosapentaenic (22:5, n-3, DPA) acids [Ackman & Ratnayake, 1992; Allen, 1995; Chen & Yeh, 2003; Dobrzański *et al*., 2002b]. The high content of these acids found in fish oils has an impact on the nutritive value of animal feed, depending on the raw material selected for oil production, *i.e.* fish species and age, time and place of fish catching, diets, gonads, and also the temperature of water resources, from which the fish have been caught. The fish living in natural aquacultures are higher in L-PUFAs than those from fish farms. Their content found in tuna fish *(Thunnus spp.)*, for example, averaged 3725 mg per 100 g of fish; 2824 mg of L-PUFA per 100 g was found in herring *(Clupea spp.)*, while only 296 mg of L-PUFA per 100 g of fish was found in carp *(Cyprinus carpio L)* [Kris-Etherton *et al*., 2002; Opinion…, 2005].

Vitamins soluble in fats (especially vitamins of groups A, D_3 and E) are another desirable constituent, especially in feed for young and high performance animals. Besides, vitamin E (α-tocopherol) added to swine diets, increases fat stability, but decreases cholesterol [Sathivel, 2002]. Fish oils also contain macro- and microelements, indispensable for metabolic processes in animals [Jamroz, 2001; Jongbloed *et al*., 2002].

Many authors [Cattaneo *et al*., 2006; Leskanich & Noble, 1997; Raes *et al*., 2004] report that fish oils (oil-feed mixtures, meal and concentrates) can improve the nutritive value of milk, eggs, meat and animal fat, depending on the chemical composition and concentration of these supplements in animal diets.

The purpose of the present study was to determine the nutritive value of raw fish oils obtained from various raw materials, taking into account the content of fatty acids, vitamins soluble in fats and macro- and microelements.

MATERIAL AND METHODS

The material taken for the study consisted of raw fish oils (RFO) obtained from a domestic manufacturer of fish meal. The raw material for fish meal and oil production consisted primarily of herring and sprat by-products, with trace amounts of salmon, mackerel, cod and trout.

Separation of fish oil. Fish oil is recovered from overcooked fish by-products, which are next pressed to obtain a pulp. Thermal exudates and press concoction (above 90°C) are directly carried into a centrifuge, which separates crude oil from the remaining fat and protein fractions. If the recovered oil contains too much water, it is additionally heated and transported to a clarifying centrifuge. In this way, crude brown

Author's address for correspondence: Zygmunt Usydus, Sea Fisheries Institute of Gdynia, ul. Kołłataja 1, 81-332 Gdynia, Poland; e-mail:zygmunt@mir.gdynia.pl

oil (of around 75°C), in liquid form at room temperature, with typical odour and density of approx. 0.9 g/mL is obtained. At the next stage, it can be purified, depending on contamination level and final destination. Crude fish oil from three batches produced on different days from 6 kinds of raw material (herring, sprat, salmon and mixed by-products) was collected in plastic containers and stored in a cool chamber.

Chemical analyses of the samples. Fatty acids (SFA, MUFA, PUFA,L-PUFA, omega-3 and omega-6) were determined using a 6890N gas chromatograph (Agilent Technologies), to a model mixture 37 fatty acids. The chromatographic analysis of fatty acids was performed after they had been esterified into appropriate methyl esters. After esterification, the purified samples were analysed, using gas chromatography with an FID detector and a 100 m long capillary column covered with an SP-2560 phase. Vitamins soluble in fat (A, D_3, E) were assayed using the HPLC method (Merck/Hitachi with a fluorescent detector and DAD). In analyses of micro and macroelements, the samples were subject to wet mineralization with nitrate acid, in microwaves, and the final determinations were made after atomization performed in a graphite oven, using a Perkin Elmer 4100 atomic absorption spectrometer. Phosphorus content was determined using an ICP-OES emission spectrometer (Varian).

The studies were carried out in an accredited laboratory at the Sea Fisheries Institute of Gdynia, using validated methods, according to the procedures required by the laboratory regulations.

RESULTS AND DISCUSSION

The data in Table 1 show that raw fish oils (RFO) not only improve the energy value of feed, but they are also a valuable source of vitamins soluble in fats, and besides, they contain L-PUFAs, healthy to humans and animals [Leskanich & Noble, 1997; Nettleton, 1985]. In addition, worth noting is a ratio of ω-3/ω-6 acids found in fish oils. The ratio of these acids in foods for animals and humans is around 0.2. It is much lower in vegetable oils and oils of animal origin. For this reason, animal fish oil added to animal feed can enhance this ratio, which can consequently prevent the risk of circulation failures and cancer diseases [Ziemlański, 1984]. The data reported by the Institute of Food and Nutrition [Kunachowicz *et al*., 1998] show that soy oils do not contain L-PUFAs, and the ratio of ω-3/ω-6 found in soy oils is 0.15. The basic component of soy oil is linoleic acid (approx. 54%) of ω-6 family, which when given in excess to rodents, can enhance the development of breast cancer [Hryniewiecki, 1998].

The richest in L-PUFAs and ω-3 acids proved to be the oil obtained from herring by-products, while the lowest amounts were found in the oil obtained from Norwegian salmon. The oils obtained from a mixture of fish by-products exhibited intermediate concentrations of these acids.

Fish oils added to animal feed are a valuable source of vitamins soluble in fats. They are especially high, as compared to vegetable oils, in vitamin D_3. Also vitamin E (α-tocopherol) present in herring and sprat waste products is higher than that present in fats of the muscle tissue of these fish. This is likely due to the fact that, as reported by Undeland *et al.* [1998], lipid content of herring waste products is three times higher in α-tocopherol than lipids extracted from the muscle tissue of these fish. The requirements of monogastric animals for these vitamins [Feeding Recommendations…1993, 2005] suggest that even trace amounts of fish oil can satisfy their needs.

Another advantage of fish oils is also a consequence of the positive ratio of hipocholesterolemic to hypercholesterolemic acids. For comparison, this ratio in oils made from herring combined with sprat is around 3, in modified fish meal oil it is 3.12 [Kołacz *et al*., 2003], and only 0.42 in milk fat, which accounts for a high content of saturated acids stimulating the synthesis of undesired cholesterol fraction [Brzóska *et al.,* 1999]. For this reason, attempts have been made to study the effects of fish oils added to feed for cows [Baer *et al.,* 2001; Donovan *et al*., 2000].

The results obtained in the study (Table 2) show that RFO are by no means rich in macro- and microelemets. The highest levels of phosphorous, calcium, magnesium, sodium, potassium and iron were found in the by-products of fish from the Baltic Sea (sprat and herring). The fish oil from Norwegian salmon was the highest in selenium (0.038 ppm), but this quantity, as compared to that found in fodder plants [Jamroz, 2001], was very low. Copper and zinc were at the levels lower than the method used for the study allowed us to determine their content (copper below 0.1 ppm, and zinc below 1 ppm). Nutritional requirements on major and trace elements for farm animals are very different, depend from chemical form of elements, age and yield (productivity) of animals [Jongbloed *et al*., 2002].

TABLE 1. Contents of vitamins and fatty acids in raw fish oils.

Raw material (by-product)	Vitamin A (mg/kg)	Vitamin D_3 (mg/kg)	Vitamin E (mg/kg)	SFA[1] (%)	MUFA[2] (%)	PUFA[3] (%)	L-PUFA[4] (%)	ω-3 (%)	ω-3/ω-6
Herring	42.70	0.63	150.2	31.6	29.0	39.4	24.74	28.88	2.77
Sprat	26.76	0.11	210.4	30.76	30.03	39.21	20.98	25.2	1.78
Herring+sprat	32.24	0.19	179.0	30.95	29.82	39.23	21.77	26.1	2.05
Norwegian salmon	15.63	0.15	110.3	20.64	46.44	39.92	16.91	20.74	1.72
Mixed: herring + sprat + Norw. salmon	19.97	0.17	168.5	25.22	41.4	33.38	18.55	21.88	1.97
Mixed: Baltic fish + Norw. salmon + trout	27.94	0.21	139.5	29.97	31.61	38.42	20.93	24.66	2.54
Soya oil	0	not determined	125.8	14.85	23.04	62.2	0	8.17	0.15

[1] saturated fatty acids; [2] monounsaturated fatty acids; [3] polyunsaturated fatty acids; [4] long- polyunsaturated fatty acids

TABLE 2. The content of macro- and microelements in raw fish oils (mg/kg).

Raw material (by-product)	Macroelement					Microelement			
	P	Ca	Na	Mg	K	Cu	Zn	Fe	Se
Herring	90.70	59.14	43.84	11.28	28.24	> 0.1	> 1.0	31.99	0.039
Sprat	134.30	65.66	25.24	10.08	25.14	> 0.1	> 1.0	32.82	0.030
Herring+sprat	116.26	60.10	36.32	10.54	24.58	> 0.1	> 1.0	33.89	0.032
Norwegian salmon	67.08	53.68	24.54	7.06	10.41	> 0.1	> 1.0	3.24	0.038
Mixed: herring+sprat+Norw. salmon	75.43	58.90	24.54	9.07	23.35	> 0.1	> 1.0	7.26	0.030
Mixed: Baltic fish+Norw. salmon+ trout	75.35	50.56	24.77	8.84	12.67	> 0.1	> 1.0	5.96	0.028

The concentrations of toxic metals (Pb, Cd, Hg, As) in the fish oils under investigation were low (Table 2). The exception was arsenic in the oils obtained from sprat waste products, the concentration of which was reaching permissive levels [Usydus & Dobrzański, 2007].

Results obtained in this study indicate that fish oils made by Polish fish processing plants are a valuable source of polyunsaturated fatty acids of ω-3 family, which are known to have a positive impact on human and animal health. Animal feed supplemented with appropriate quantities of fish oils improves the nutritive value of eggs, milk, animal meat and fat. The improvement of the nutritive value of animal feed supplemented with fish oils is also due to the presence of vitamins soluble in fats, especially vitamins D_3 and E.

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BADANIA NAD WARTOŚCIĄ POKARMOWĄ PASZOWYCH OLEJÓW RYBNYCH

Zygmunt Usydus[1], Lucyna Polak-Juszczak[1], Zbigniew Dobrzański[2], Małgorzata Malesa-Ciećwierz[1]

[1]Morski Instytut Rybacki w Gdyni; [2]Katedra Higieny Zwierząt i Ichtiologii Uniwersytet Przyrodniczy we Wrocławiu

Celem pracy jest ocena chemiczna surowych olejów rybnych uzyskiwanych z odpadów technologicznych z przetwórstwa różnych gatunków ryb (śledź, szprot, łosoś norweski, pstrąg) pod kątem ich wartości pokarmowej w żywieniu zwierząt gospodarskich. Określano skład kwasów tłuszczowych, ze szczególnym uwzględnieniem wielonienasyconych kwasów tłuszczowych z rodziny ω-3. (PUFA n-3). Oceniano także zawartość witamin rozpuszczalnych w tłuszczach (A, E, D_3) oraz podstawowych makroelementów i wybranych mikroelementów. Stwierdzono, że oleje rybne charakteryzują się bardzo korzystnym składem kwasów tłuszczowych, znaczną zawartością witamin D_3 i E, a także fosforu, wapnia, sodu, potasu i żelaza. Stosowanie olejów rybnych w określonych dawkach jako dodatków do pasz dla zwierząt gospodarskich może korzystnie wpływać na wartość odżywczą produktów pochodzenia zwierzęcego (mleko, jaja, mięso, tłuszcze), wzbogacając je w bioaktywne i prozdrowotne składniki.