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Food of marine origin: Between benefits and potential risks. Part I. Canned fish on the Polish market

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ABSTRACT

Chemical analyses were performed on 12 of the most popular varieties of canned fish on the Polish market. The contents of the nutritive substances of canned fish (protein, micro and macroelements, vitamins A_1, D_3, E, and fatty acids) and certain contaminants were determined. It was confirmed that canned fish is a good source of digestible proteins, fluoride, iodine, selenium, and vitamin D_3. The fundamental nutritive benefit of processed fish is the highly advantageous fatty acid composition, which imparts healthful effects. The high content of long-chained polyunsaturated fatty acids, which is not noted in other food products, is especially important.

Most contaminants occurred at low levels. However, the contents of dioxins may pose a problem; although the concentrations of these pollutants in the canned products tested did not exceed permitted levels (4pg TEQ-WHO/g for dioxins/furans), they are relatively high in canned Baltic fish.

The health benefits and risks stemming from canned fish consumption were determined according to the provisional tolerable weekly intake (PTWI) for contaminants and the quantities of ingredients that render a fish diet healthy, based on data from The EFSA Journal (2005) [EFSA (European Food Safety Authority) (2005). Opinion of the scientific panel on contaminants in the food chain on a request from the European parliament related to the safety assessment of wild and farmed fish. *The EFSA Journal 236,* 1–118].

The benefits of fish and canned fish consumption outweigh the risks and the species and quantity of fish consumed is of significance to the consumer.

1. Introduction

Due to their nutritional value, fish and canned fish products are high quality foods that are beneficial to human health. The low consumption of fish and canned fish products in Poland, as compared to that in other European countries (5.8 kg/per capita, including about 1.5 kg of canned fish), is due, among other reasons, to inadequate promotion and a lack of sufficient information about their nutritional qualities.

Fish and canned fish are sources of protein rich in essential amino acids, micro and macroelements (calcium, phosphorus, fluorine, iodine), fats that are valuable sources of energy, fat-soluble vitamins, and unsaturated fatty acids that, among other benefits, have a hypocholesterolic effect (anti-arteriosclerosis) (Ismail, 2005). In comparison to the meat of slaughter animals, that of fish is rich in phosphorus, potassium and magnesium, and the calcium content of small-boned fish is also high. Marine fish and products made from them are the primary natural source of dietary iodine. They are also rich in microelements, such as selenium, fluorine and zinc.

The fundamental difference between fish and other animal or plant fats stems from its exceptionally advantageous content of fatty acids that stems from the high level of essential unsaturated fatty acids, such as docosahexaenoic (22:6, n-3, DHA), eicosapentaenoic (20:5, n-3, EPA), and docosapentaenoic (22:5, n-3, DPA).

The quantity and quality of dietary fats have recently come under scrutiny by many nutritionists and doctors due to the role these substances play in the development of some diseases and pathological states, especially in the development of cardiac and circulatory disorders. It is estimated that the consumption of one portion of fatty fish, daily, delivers about 900 mg/day of n-3 acids (e.g., EPA and DHA), and that this quantity is advantageous in reducing mortality in patients with coronary diseases (Kris-Etherton, Harris, & Appel, 2002).

In contrast to the indisputable advantages of fish in the diet, also the potential risk of exposure to the chemical contaminants contained in fish and fish products should be taken into consideration in assessment of the health quality of this food. It is well

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known that fish can contain toxic metals (mercury, arsenic, lead, and cadmium), polychlorinated biphenyls (PCBs), organochlorine pesticides, and aromatic hydrocarbons but above all else, however, fish (especially those from the Baltic) are a potential source of human exposure to such toxic contaminants as dioxin-like polychlorinated biphenyls (dl-PCBs), polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), polybrominated diphenyl ethers (PBDEs), polychlorinated diphenyl ethers (PCDEs) or polychlorinated naphthalenes (PCNs) (Isosaari et al., 2003). Dioxins, furans, and dl-PCBs are all persistent organic pollutants (POPs) and have been classified by the International Agency for Research on Cancer (IARC) as group A carcinogens, which, places them among such substances as benzo(a)pyrene, aflatoxin, and nitrosamines. People can be exposed to POPs from various sources; however, 90% of dioxin exposure comes through food, including approximately 7% of it from fish (Piskorska-Pliszczynska, Kowalski, Wijaszka, & Grochowalski, 2005).

In recent years, investigations aimed at identifying the benefits of fish consumption have also indicated that there are risks connected with toxic contamination (Domingo, Bocio, Falo, & Llobet, 2007; Mahaffey, 2004). It is difficult to find a balance between the health benefits and risks stemming from fish consumption or even, indeed, to draw any conclusion about this issue.

The aim of the current study was to conduct tests to determine the quantity of the healthy components in canned fish (approximately 23.4% of the fish consumed in Poland is canned) as well as the contents of selected toxic substances. The second section of the paper presents the results of investigations of other fish products on the Polish market. The authors would like to contribute to the general understanding of the risks and benefits of consuming fish and fish products.

2. Materials and methods

2.1. Samples for testing

The twelve most popular varieties of canned fish on the Polish market, produced by the largest manufacturers and distributors in the country, were identified. Throughout 2005, ten different lots of each variety were collected, and each was comprised of 8–10 cans. The samples were purchased in large supermarkets, grocery stores, or directly from the manufacturers. The following varieties of canned products were chosen for the study:

1. Popular sprat in tomato sauce.
2. Sprat in oil.
3. Caro Sprat in oil.
4. Paprykarz (fish spread with rice).
5. Herring in tomato sauce.
6. Gdansk herring.
7. Herring fillets in tomato sauce.
8. Tuna in oil.
9. Mackerel fillets in tomato sauce.
10. Mackerel fillets in oil.
11. Sardine in oil.
12. Herring fillets in oil.

Tested products comprised 71.4% of the raw material used by manufacturers for production of canned fish. Moreover, 16.2% of the production was of fish spread with rice (paprykarz).

The health benefits and risks stemming from canned fish consumption were determined according to the provisional tolerable weekly intake (PTWI) for contaminants and the quantities of ingredients that render a fish diet healthy, based on data from the EFSA Journal (2005).

2.2. Study methods

2.2.1. General

Most of the chemical testing was performed at the Accredited Testing Laboratory of the Sea Fisheries Institute in Gdynia. The analyses were conducted with validated methods according to the testing procedures that are binding at the Accredited Testing Laboratory of the Sea Fisheries Institute (Accreditation Certificate no. AB 017 awarded by the Polish Center of Accreditation, in accordance with PN-EN ISO/IEC 17025:2001 standard, based on PN-EN ISO 8294 and PN-EN ISO 12193 standards.

The tests were performed as described below:

2.2.2. Mineral components

These were determined by atomic absorption spectrometry. Samples for testing the contents of most of the micro and macroelements were wet-mineralized with concentrated nitric acid in MD-2100 microwave ovens (CEM Corporation) and the final determinations were performed by the atomic absorption method in a graphite furnace with a Perkin Elmer 4100 atomic absorption spectrometer with plasma excitation, using a VISTA-MPX emission spectrometer. Mercury analysis was performed with flameless atomic absorption spectrometry, using an Altec AMA-254 spectrophotometer. Iodine and fluorine contents were assayed at the Accredited Chemical Laboratory of Multielemental Analyses at the Wrocław University of Technology. Iodine was determined by a spectrometric method, using the ICP-OES technique, and fluorine measured by means of an ion-selective electrode.

2.2.3. Fat-soluble vitamins (A_1 – all-trans-retinol, D_3 – cholecalciferol, E – α-tocopherol

The determination of fat-soluble vitamins was performed by high-performance liquid chromatography with a Merck/Hitachi chromatograph equipped with a fluorescence (for A_1 and E determination) and UV (for D_3 determination) detector. Freeze-dried samples were saponified and vitamins were extracted with hexane and then, following extraction, purification and concentration, final determinations were performed.

2.2.4. Organochlorine pesticides (OCP) and polychlorinated biphenyl (PCB_7)

Freeze-dried samples were extracted with hexane in a Soxtec Avanti apparatus. The solvent was evaporated. An aliquot of lipid was dissolved in hexane and treated with a mixture of (1:1 v/v) concentrated sulfuric acid and 30% fuming sulphuric acid for 3 h. After centrifuging and freezing the lower layer at a temperature of -50 °C, the clean hexane extract was separated and the lower layer was re-extracted with hexane. Hexane extracts were combined and the organochlorine pesticides and PCBs contained in it were assayed by capillary gas chromatography (GC-8000 gas chromatograph by Fisons) with an electron capture detector on a DB-5 column, 60 m in length. Quantification was carried out on the basis of area of standard peaks.

2.2.5. Fatty acids

Freeze-dried samples were extracted with mixture of (4:1) hexane: acetone in the Soxtec Avanti apparatus. The fatty acid contents were determined by the chromatographic method on a gas chromatograph coupled with a mass spectrometer (GC/MS – mass spectrometer by Varian, Saturn 2000) using standard mixtures. The chromatographic analysis of the fatty acids was performed after they had been put through the appropriate methyl ester. Following esterification, the purified and neutralized extracts were analyzed by the GC/MS technique with the help of a Rtx-5 MS capillary column of length of 30 m.

2.2.6. Basic nutritional components

Dry weight, total protein, fat, chlorides, ash and digestible protein were determined in the SFI Accredited Laboratory, based on Polish standards and the methodology outlined in AOAC (1990).

2.2.7. Dioxins and PBDEs

Polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), dioxin-like polychlorinated biphenyls (dl-PCBs), and polybrominated diphenyl ethers (PBDEs). The tests were conducted at the Accredited Laboratory of the Institute of Public Health in Ostrava, Czech Republic. Accredited methods were used in the testing on a high resolution mass spectrometer (HRGC/HRMS), using a variety of standard analytical procedures in accordance with regulations of the European Union and WHO (Council Regulation (EC) No: 2375/2001 of 29 November, 2001).

3. Results

3.1. General

Tables 1 and 2 present the results of tests to determine the nutritional components and the organic and inorganic contami-

Table 1
Average contents of nutritive components (unit/100 g wet weight) in canned fish (standard deviations – SD)

		1[a]	2	3	4	5	6	7	8	9	10	11	12
Total protein	(g)	11.5 (0.74)	15.0 (1.24)	11.4 (0.92)	6.7 (1.65)	12.7 (1.63)	15.1 (1.43)	11.3 (1.05)	15.7 (2.42)	12.7 (0.88)	13.7 (1.69)	16.7 (1.49)	13.7 (2.12)
Digestible protein	(g)	10.46 (0.47)	13.85 (0.48)	10.6 (0.33)	5.2 (1.15)	11.5 (0.56)	14.4 (0.36)	10.2 (0.35)	14.7 (0.51)	11.7 (0.30)	12.8 (0.44)	15.9 (0.25)	13.1 (0.17)
Total fat	(g)	5.38 (1.93)	32.89 (4.39)	22.8 (3.25)	6.6 (2.72)	6.21 (1.85)	30.1 (6.02)	9.0 (4.66)	27.2 (5.59)	8.5 (3.39)	36.3 (6.99)	27.3 (8.06)	29.9 (9.61)
EPA	(mg)	190 (65.3)	625 (288.4)	537 (140.1)	197 (139)	295 (147)	758 (420)	407 (213)	43 (22.6)	301 (107)	651 (311)	848 (226)	786 (322)
DHA	(mg)	238 (74.8)	1035 (250.6)	991 (169.0)	258 (194)	408 (238)	1123 (687)	646 (348)	209 (56.8)	602 (174.9)	1148 (539)	979 (314)	1103 (248)
L – PUFAs	(mg)	504 (95)	1724 (301)	1653 (201)	533 (211)	743 (320)	1948 (759)	1112 (392)	259 (59)	1041 (205)	1989 (622)	2115 (425)	1990 (406)
Calcium	(mg)	246 (27.8)	339 (34.6)	269 (83.8)	199 (102.2)	240 (44.4)	278 (88.7)	118 (45.8)	47.3 (18.9)	92.4 (53.7)	72.7 (28.0)	522 (252.4)	92.4 (53.7)
Phosphorus	(mg)	205 (27.4)	301 (44.5)	202 (5.5)	119 (35.9)	197 (29.9)	226 (25.1)	138 (12.2)	129 (17.6)	128 (25.9)	146 (49.4)	339 (53.8)	172 (55.1)
Selenium	(μg)	5.8 (2.2)	14.7 (3.3)	12.1 (2.2)	10.3 (9.6)	12.8 (3.7)	17.6 (7.3)	13.5 (2.6)	29 (9.3)	16.2 (2.7)	14.9 (3.7)	25.5 (18.0)	16.2 (2.7)
Fluorine	(mg)	1.54 (0.55)	2.88 (0.8)	1.62 (0.48)	1.47 (0.52)	1.39 (0.48)	2.46 (0.62)	1.26 (0.45)	1.64 (0.49)	1.51 (0.62)	2.04 (1.11)	2.7 (0.46)	1.79 (0.63)
Iodine	(mg)	0.05 (0.04)	0.08 (0.06)	0.05 (0.02)	0.03 (0.01)	0.03 (0.02)	0.05 (0.02)	0.04 (0.02)	0.39 (0.24)	0.03 (0.01)	0.08 (0.02)	0.18 (0.12)	0.08 (0.03)
Vitamin A_1	(μg)	122 (65.5)	376 (101.5)	87 (45.0)	52.7 (42.0)	28 (19)	20.2 (7.5)	19.5 (6.7)	8.9 (4.3)	38.2 (20.7)	22.0 (8.7)	11.3 (7.0)	20.5 (8.0)
Vitamin D_3	(μg)	3.8 (1.9)	10.4 (3.2)	3.3 (2.0)	2.0 (1.7)	0.8 (0.1)	2.6 (0.8)	1.2 (0.9)	0.9 (0.6)	2.7 (1.6)	3.0 (2.8)	2.9 (1.9)	3.3 (1.6)
Vitamin E	(μg)	1013 (641.8)	1128 (729.0)	1995 (761.0)	683 (330.0)	688 (316.0)	2966 (751.8)	689 (210.0)	1741 (946.4)	294 (90.1)	2256 (791.4)	1452 (502.8)	1563 (349.0)

[a] 1.2.. . ..12 – Variety of canned products as listed in point 2.1.

Table 2
Average contents of organic and inorganic contaminants (unit/1000 g wet weight) in canned fish (standard deviations – SD)

		1[a]	2	3	4	5	6	7	8	9	10	11	12
Mercury	(μg)	16 (3.1)	25 (6.0)	18 (3.7)	6 (0.9)	18 (9.6)	35 (16.8)	37 (17.5)	67 (25.9)	28 (16.8)	96 (80.5)	24 (16.8)	38 (16.8)
Cadmium	(μg)	20 (2.9)	25 (10.1)	19 (9.6)	23 (6.8)	21 (9.2)	10 (7.0)	8 (4.5)	36 (15.0)	14 (11.5)	11 (8.7)	41 (31.1)	10 (8.8)
Lead	(μg)	29 (5.8)	30 (13.7)	33 (3.1)	25 (14.1)	20 (12.9)	33 (21.7)	14 (6.1)	10 (1.4)	27 (21.6)	23 (17.5)	57 (35,4)	43 (22.2)
Arsenic	(μg)	869 (431)	912 (230)	1030 (267)	474 (115)	670 (324)	896 (403)	977 (268)	1050 (396)	1205 (390)	1217 (423)	1933 (854)	1427 (390)
PCDD/Fs	ng WHO-TEQ	1.8 (0.4)	2.6 (0.5)	2.4 (1.6)	0.7 (0.3)	1.9 (0.3)	1.8 (0.4)	0.6 (0.3)	0.36 (0.01)	0.28 (0.22)	0.33 (0.14)	0.68 (0.49)	1.0 (0.6)
dl-PCB	ng WHO-TEQ	2.3 (0.3)	3.0 (0.3)	2.8 (0.4)	0.9 (0.2)	1.7 (0.3)	1.8 (0.3)	0.8 (0.3)	0.03 (0.00)	0.62 (0.33)	0.76 (0.16)	2.26 (1.86)	1.2 (0.8)
PCDD/Es + dl-PCB	ng WHO-TEQ	4.1 (0.7)	5.6 (0.8)	5.2 (1.9)	1.6 (0.5)	3.6 (0.5)	3.6 (0.7)	1.4 (0.5)	0.39 (0.01)	0.9 (0.4)	1.09 (0.2)	2.94 (2.1)	2.2 (1.1)
PBDEs	(ng)	587 (103)	863 (105)	745 (96)	329 (73)	693 (290)	629 (79)	659 (256)	51 (15)	531 (120)	1641 (1184)	744 (369)	1214 (688)
Σ DDT	(μg)	27.1 (15.0)	36.0 (7.6)	20.6 (6.8)	7.4 (2.7)	21.5 (18.9)	24.9 (7.4)	5.7 (3.4)	0.32 (0.19)	1.58 (0.9)	2.57 (1.4)	1.94 (1.2)	9.47 (3.6)
HCB	(μg)	0.96 (0.6)	3.15 (0.6)	2.36 (1.6)	1.39 (0.4)	2.03 (1.2)	5.0 (3.8)	2.44 (1.2)	1.37 (0.9)	3.4 (2.2)	2.86 (2.6)	3.42 (2.8)	8.24 (3.9)
Σ HCH	(μg)	1.84 (1.5)	2.12 (0.5)	0.90 (0.6)	0.48 (0.3)	1.86 (1.5)	1.32 (0.7)	0.43 (0.3)	0.35 (0.22)	0.24 (0.15)	0.35 (0.25)	0.81 (0.7)	0.94 (0.5)
Σ PCB_7	(μg)	23.5 (13.4)	35.7 (12.0)	23.2 (14.2)	9.7 (2.4)	20.8 (16.2)	24.7 (7.8)	7.6 (3.9)	9.2 (4.5)	6.7 (3.2)	9.6 (6.5)	12.8 (8.2)	20.8 (11.2)

[a] 1.2.. . ..12 – Variety of canned products as listed in point 2.1.

nants in the 12 varieties of canned fish investigated. Each result is the mean of ten different lots of sample. Each lot was represented by a sample comprised of 8–10 cans. Minimum and maximum values are presented in parentheses. Table 3 presents the mean values of certain ingredients of canned products made of various fish species (sprat, herring, mackerel, sardine, tuna) and for paprykarz, which can contain different fish species and rice. The numbers of cans containing the recommended quantity of given ingredients are included in parentheses. Table 4 gives the quantities of canned products that contain the PTWI. Table 5 presents the percentage of the PTWI and the recommended weekly allowance of nutrients for Poles who consume an average of 30 g of canned fish per week.

Table 3
Average contents of certain components in canned fish, depending on the raw material used for their manufacture (quantity of product in g containing the recommended content of a given component)

		Canned sprat	Canned herring	Canned mackerel	Canned sardine	Canned tuna	Paprykarz	Weighted average[b]	Recommended amount	PTWI[a]
Nutritive components										
EPA + DHA	(mg/100 g)	1172 (42.7)	1350 (37.0)	1356 (36.9)	1827 (27.4)	252 (198.4)	455 (109.9)	1120 (44.6)	500 mg/day	
Fluoride	(mg/100 g)	2.06 (121.4)	1.73 (144.5)	1.68 (148.8)	2.7 (92.6)	1.64 (152.4)	1.39 (179.9)	1.80 (139.0)	2.5 mg/day	
Iodine	(mg/100 g)	0.06 (266.7)	0.05 (320)	0.06 (266.7)	0.18 (88.9)	0.39 (41.0)	0.03 (533.3)	0.08 (200.0)	0.16 mg/day	
Vitamin D_3	(mg/100 g)	5.8 (43.1)	2.0 (125)	2.9 (86.2)	2.9 (86.2)	0.9 (277.8)	2.0 (125.0)	3.0 (83.3)	2.5 μg/day	
Contaminants										
Cadmium	(μg/kg)	21	12	13	41	36	23	19		7 μg/kg/ body weight
Mercury	(μg/kg)	20	32	62	24	67	6	31		1.6 μg/kg/ body weight[c]
Lead	(μg/kg)	31	28	25	57	10	25	29		25 μg/kg/body weight
Arsenic	(μg/kg)	937	993	1211	1933	1050	474	986		25 μg/kg/body weight
PCDD/PCDF	ng WHO-TEQ/kg	2.27	1.32	0.30	0.68	0.36	0.70	1.16		
dl-PCB	ng WHO-TEQ/kg	2.7	1.38	0.69	2.26	0.03	2.3	1.73		
PCDD/PCDF + dl-PCB	ng WHO-TEQ/kg	4.97	2.7	0.99	2.94	0.39	3.3	2.89		14 pg/kg/body weight
PBDEs	(ng/kg)	732	799	1086	744	51	329	746		0.7 μg/kg/body weight

[a] PTWI – provisional tolerable weekly intake.
[b] Weighted average in relation to 100% of canned product taking into consideration the raw material used in its manufacture.
[c] Methylmercury content – assumed that total mercury occurred as methylmercury.

Table 4
Amount of canned product (g) containing the PTWI[a] of certain organic and inorganic contaminants

	Canned sprats	Canned herring	Canned mackerel	Canned sardines	Canned tuna	Paprykarz	Weighted average
Cadmium	23330	40830	37690	11950	13610	21304	25790
Mercury	5600	3500	1806	4666	1672	18666	3613
Lead	56452	62500	70000	30702	175000	70000	60345
Arsenic	1868	1762	1445	905	1667	3692	1775
PCDD/PCDF + dl-PCB	197	363	980	331	2513	272	327
PBDEs	66940	61327	45120	65860	960784	148936	65684

[a] On a male adult weighing 70 kg.

Table 5
Percentage of recommended weekly allowance and PTWI intake by the average Pole[a] from canned fish consumption

		Canned sprats	Canned herring	Canned mackerel	Canned sardines	Canned tuna	Paprykarz	Weighted average
EPA + DHA	(%)	10.02	11.57	11.62	15.66	2.16	3.9	9.6
Fluorine	(%)	3.53	2.97	2.88	4.63	2.81	2.38	3.09
Iodine	(%)	1.61	1.34	1.61	4.82	10.45	0.81	2.15
Vitamin D_3	(%)	9.53	3.29	4.77	4.77	1.48	3.29	5.14
Contamination (% PTWI)								
Cadmium	(%)	0.13	0.07	0.08	0.25	0.22	0.14	0.12
Mercury	(%)	0.54	0.86	1.66	0.64	1.79	0.16	0.83
Lead	(%)	0.05	0.05	0.04	0.10	0.02	0.04	0.05
Arsenic	(%)	1.61	1.70	2.08	3.31	1.8	0.81	1.69
PCDD/PCDF + dl-PCB	(%)	15.21	8.27	3.06	9.08	1.19	11.02	9.24
PBDEs	(%)	0.045	0.049	0.066	0.046	0.003	0.02	0.046

[a] Average annual canned fish consumption in Poland is 1.5 kg.

3.2. Nutritional ingredients

The mean quantities the nutritional components of all the tested products were as follows: protein – 13.1%, fat 20.16%, dry mass 37.40%. The protein in the canned fish products was of high quality, as over 90% of it was digestible (91.6%). The mean energy in the tested products was 240 kcal/100 g of which 25% came from protein, 69% from fat, and 6% from carbohydrates. The lowest protein content was determined in the paprykarz with a mean of 6.71%. The protein in these products was the least digestible, at 77%, probably due to the presence of plant protein (rice), which is known to be less digestible. It was revealed that 100 g of canned product, with an average ingredient composition, met 27% of the fat, 17% of the protein, and 11% of the daily energy requirements of an adult.

The proportions presented above differ when products in tomato sauce and oil are considered individually.

A quantity of 100 g of fish product canned in tomato sauce meets approximately 10% of fat, 14% of protein, and 5.5% of energy daily requirements while that canned in oil meets approximately 40% of fat, 18% of protein, and 14% of daily energy requirements.

Canned fish products are rich in macro and microelements. The basic macroelements essential to proper body function are calcium and phosphorus, and the possibility of utilizing these elements depends on their mutual ratios in the foods consumed. Currently, it is thought that the weight ratio of calcium to phosphorus should be 1.3:1 (Brzozowska, 2000). The current tests indicated that this ratio in all of the tested canned fish products was 1.11:1 and, as such, is close to the optimal. Canned fish is a good source of calcium and phosphorus. The recommended daily allowance of calcium is contained in an average of about 420 g of canned fish while that of phosphorus is found in about 365 g. Canned sardines had the highest levels of calcium and phosphorus and as little as 200 g of such products meets the daily adult requirement for these elements. The lowest contents of these macroelements were noted in canned flaked fish or fillets (canned tuna and mackerel).

In comparison to other food products, canned fish are very rich in fluorine and iodine. A 140 g portion of the average tested canned product meets the recommended daily requirement of adults for fluorine while, for iodine, 180 g of the average tested canned product is sufficient. Canned sprat contained the most fluoride, while tuna had the highest iodine content.

Canned fish products are also rich in selenium, deficiencies of which might be a risk factor for cancer (Smrkolj, Pograjc, Hlastan-Ribi, & Stibilj, 2005). The recommended daily selenium allowance for adults is met by an average of 400 g of the tested canned fish products. Tuna had the highest levels of this element, and as little as 200 g of this fish should be sufficient for meeting selenium needs. Other microelements tested occurred at relatively low levels. Only in canned sprat was the zinc content higher in relation to that noted in other canned products.

The content of fat-soluble vitamins varied widely among the canned fish products, as well as within single products. The mean contents of vitamins A_1, D_3, and E in 100 g of all the tested products were 67, 3, and 1347 μg, respectively, which corresponded to 10%, 60%, and 15% of the recommended daily allowance of these vitamins.

The daily requirement of vitamin D_3 is met by as little as a one 170 g portion of canned fish. Sprats in oil were the richest of this vitamin and supplied the daily requirement in as little as 50 g of product. The mean contents of vitamins A_1 and E in the tested canned products occurred at relatively low levels in comparison with other food products of animal origin or in plant oils (Kuchnowicz, Nadolna, Przygoda, & Iwanow, 1998).

One of the nutritional pluses of fish and fish products is that the fats they contain have advantageous fatty acid profiles, which are what renders them nutritionally beneficial. Especially, significant, and something not found in other food products, is the high content of LC-PUFAs (EPA and DHA), which have a prophylactic effect in the prevention of circulatory disorders and lower the mortality of patients with coronary diseases (Kris-Etherton et al., 2002). Canned sardine contains the highest amounts of these acids, while tuna has the least of them, and as little as 30 g of sardine meets the recommended daily allowance for these acids. Canned mackerel and herring have also been confirmed to have high contents of these acids. The mean content of these acids (calculated as the weighted average stemming from the quantity consumed of a given group of canned products) in 100 g of canned fish is 1120 mg; thus, approximately 45 g of these products meets the daily requirement for EPA and DHA.

Consideration of fats occurring in canned fish must also address the ratio of n-3/n-6 acids. The appropriate ratio in food can contribute to improved general health, reduce the risk of cancer, and have a beneficial impact on the immune system. This ratio (n-3:n-6), recommended by nutritionists, should on average be about 0.2 with the consumption of about 8 g of essential unsaturated fatty acids (EUFA). However, numerous studies have indicated that the optimal ratio of these acids should refer to the disease which is under consideration (Simopoulos, 2002). In the case of canned fish products, the mean ratio of these acids is 1.1, but in "Herring fillets in tomato sauce" this ratio is as high as 2.75. From a nutritional point of view, such a high proportion of n-3:n-6 acids in canned fish is beneficial and helps to ensure that the total daily intake in the human diet is sufficient, since the ratio of these acids in other foods is much lower than that recommended.

Consideration of the fatty acids in the fat of canned fish products cannot exclude the highly advantageous ratio of hypocholesterolic (unsaturated fatty acids + C18:0) to hypercholesterolic (C14:0 + C16:0) acids (DFA/OFA), the mean ratio of which is 4, while the most advantageous ratio is found in canned sardines in oil at 7.87. This indicates that the fatty acids occurring in the fats of canned fish products have a beneficial impact on the level of LDL cholesterol (low density lipoprotein) reducing the risk of atherosclerosis and coronary diseases (Kolacz et al., 2004).

3.3. Contamination

An evaluation of the content of toxic metals in canned fish products was performed, based on the permissible limits set forth in Commission Regulation (EC) no. 78/2005 of January 19, 2005. In none of the tested canned fish samples did the amounts of lead, mercury, or arsenic exceed the permissible limits. Only in three samples of canned sardine were excess limits of cadmium confirmed. These canned products also had the highest contents of lead and arsenic. The mean contents of the tested metals were relatively low, especially in the products made from Baltic fish. The contents of cadmium, lead, mercury and arsenic were, respectively, 40%, 15%, 7.0%, and 26% of the permissible limits. The mean results of mercury content in tuna and mackerel are comparable with the data reported by researchers from the United States (Shim, Dorworth, Lasrado, & Santerre, 2004).

It should also be emphasized that, in reference to the PTWI, the quantity of toxic metals ingested by the average Pole who consumes 1.5 kg of canned fish annually is an insignificant percentage of the permissible limit at 0.05% for lead and 1.69% for arsenic (Table 4). Another way to illustrate this is as follows: in order for an average Pole weighing 70 kg to ingest the permissible limit of, for example, lead, he would have to consume 60.3 kg of canned fish weekly. To reach the arsenic limit, the same Pole would have to consume 1.8 kg of canned products (Table 4).

The results presented for contents of OCP (α, β, γ HCH as the sum of HCH, HCB, and pp′-DDE, pp′-DDD, pp′-DDT as the sum of DDT) and PCB_7 (total of congeners IUPAC nos. 28, 52, 101, 118, 138, 153, 180) in the tested canned products were low relative to the permissible limits binding in some European Union countries (FAO, 1989). None of the tested samples were found to exceed the permissible limits of OCP/PCB; furthermore, in this study, mean quantities of OCP and PCB_7 were just 1% of the permissible value. The lowest contents of OCP and PCBs were noted in canned products made of fish from outside the Baltic Sea (tuna, sardine, mackerel). The highest values of Σ DDT and Σ PCB were noted in a single sprat sample at 4.1% and 4.7%, respectively, of the permissible limit. In relation to the permissible limits of OCP and PCB, the contents of these compounds in the tested canned fish products are negligible. For the average weekly consumption of the average Pole, the intake of Σ DDT is 284 ng and that of Σ PCB_7 is 624 ng.

The contents of PCDD/PCDFs and dl-PCBs (a total of 4 congeners of non-*ortho* PCB – nos. 77, 81, 126, 169 and 8 congeners of mono-*ortho* PCB – nos. 105, 114, 118, 123, 156, 157, 167, 189), in the tested canned products, given as sum of WHO-TEQs, were compared to permissible values set forth in Council Regulation (EC) No. 199/2006 of February 3, 2006 and to the PTWI for a person weighing 70 kg at 14 pg WHO-TEQ/kg of body weight (EFSA, 2005). The contents of PCDD/Fs and dl-PCBs were not noted to have exceeded the permissible limits in any of the samples. The amounts of PCDD/Fs and dl-PCB consumed weekly by the average Pole from canned fish products are 4.2% and 5.04%, respectively, of the permissible limit. Canned sprats had the highest contents of dioxin and furans and dl-PCB, while the lowest levels of these contaminants were noted in fish from outside the Baltic Sea region (tuna, mackerel, sardines).

The tests of the levels of PBDEs (total of 7 congeners – BDE-28, BDE-47, BDE-100, BDE-99, BDE-154, BDE-153, BDE-183) indicated that the highest average content of these compounds was found in canned mackerel and the lowest in tuna. Studies conducted in Ireland also indicated that the lowest levels of PBDEs were found in canned tuna (Tlustos, McHugh, Pratt, & Mc Govern, 2006). The average mean content of PBDEs in the tested canned products was 0.746 ng/g wet weight (within the range 0.04–2.748 ng/g). According to EFSA (2005), the mean content of PBDEs (based on data from six European countries) in fish and crustaceans is estimated to be 1.78 ng/g. Since the recommended PTWI (EFSA, 2005) is 1.75 μg/kg body weight, this limit is high in comparison to the content of these contaminants in the tested canned products. The average Pole, weighing 70 kg, ingests, from canned fish products, only 0.05% of the PTWI for PBDEs (Table 5).

4. Discussion

Two conflicting views regarding the importance of fish consumption in the human diet are presented in the world literature. The main themes of the discussion are the benefits for consumer health to be had from the nutritional properties of fish, especially from constituent n-3 fatty acids, and the risks posed by the contamination of fish with dioxin-like substances and methylmercury.

In an effort to reduce the risk of heart disease, the American Heart Association (AHA) recommends consuming at least two 3 oz (2×85 g) portions of fish, especially fatty fish, weekly (AHANC American Heart Association Nutrition Committee, 2006). This is due to the very advantageous fatty acid profiles of these foods, which have a protective effect against coronary heart disease (CHD).

The most recent reports (Engler & Engler, 2006; Gebauer, Psota, Harris, & Kris-Etherton, 2006; Sidhu, 2003) confirm that n-3 fatty acids have a beneficial impact on health. As reported by Engler and Engler (2006), diets containing polyunsaturated fatty acids from the n-3 family, especially EPA and DHA, play an important role in cardiovascular health and disease. Clinical trials have provided significant evidence that permits recommending diets rich in n-3 fatty acids for the treatment of heart disease. The benefits of the protective effects of n-3 fatty acids on heart disease may be multiplied by the physiological impact of lipids on blood pressure, blood vessel function, heart rhythm, platelet function, and inflammation.

Sidhu (2003) reported, additionally, that the nutritional benefits of fish consumption are related to the exploitation of its protein of high biological quality and the provision of valuable mineral compounds and vitamins.

In order to reduce the risk of coronary disease, it is recommended to maintain a dietary intake of approximately 500 mg/day of EPA and DHA. The recommended dose for those with coronary disease is 1 g/day. In addition to n-3 fatty acids (EPA and DHA), the recommended diet should contain α-linoleic acid (ALA) to enhance the nutritional values and prophylactics against heart disease (Gebauer et al., 2006). These recommendations are based on a vast number of research reports and have been endorsed by many international health organizations. In light of this, the canned fish products tested in the current study, which contain 1.12 g of EPA and DHA and approximately 0.85 g of ALA in an average of 100 g of product, are an alternative for meeting the recommended intake of these acids.

Research conducted by Norat et al. (2005) indicated that the risk of contracting colorectal cancer is lower in people who consume fish than it is in those who consume only red meat. Similar results were reported by English et al. (2004).

Fatty acids from the n-3 family, contained in fish, substantially reduce the possibility of sudden death in men who do not exhibit any symptoms of coronary disease. One meal of fish per week is sufficient to substantially reduce the risk of sudden death caused by heart disease (Albert et al., 2002). Additionally, in people over the age of 65 whose diet included moderate tuna consumption, the rate of death from ischemic heart disease (IHD) was confirmed to be lower (Mozaffarian et al., 2003).

The benefits of consuming fish and fish products can be disputed due to the contamination of these foods with methylmercury and, especially, dioxin-like compounds.

Since the mercury contamination of the tested canned fish products (it was assumed that 100% of the total mercury was methylmercury) was low in relation to the permissible limits, especially in Baltic fish (20 μg/kg on average in canned sprats; 32 μg/kg on average in canned herring), the issue of methylmercury toxicity is not discussed. Based on data from the US EPA (2000), it can be concluded that, with an average mercury (methylmercury) content of 31 μg/kg, a person weighing 70 kg can consume 16 portions of canned fish of 227 g monthly, with no cancer health concerns. The maximum number of portions of tuna, which has the highest mercury content, at an average of 67 μg/kg, would be 12. It must be emphasized that the average monthly consumption of canned fish products in Poland is just 125 g.

It was reported that some fish species, especially fat Baltic fish (salmon, sprats, herring) have elevated contents of dioxin and dioxin-like polychlorinated biphenyls (Isosaari et al., 2006). The cancer concerns of these compounds depend on the intakes and exposure times. The EC SCF and JECFA established the tolerable limit of dioxin intake in 2001 (EC SCF, 2001, WHO, 2001). The SCF set the PTWI at 14 pg WHO TEQ/kg of body weight (EC, 2001). The JECFA set the PTMI (provisional tolerable monthly intake) at 70 pgWHO-TEQ/kg of body weight (WHO, 2001). In light of these data, as well as those for dl-PCB (Table 4), the average weekly consumption of canned fish by a person weighing 70 kg can be 327 g, but only 197 g of canned sprats and 2513 g of canned tuna. The US EPA (2000) guideline presents data for the limits of fish consumption, with regard to cancer concerns, for the ingestion of PCDD/F by a person weighing 70 kg, based on exposure for a period of 70 years. In light of these data the monthly limit for canned fish consumption with a mean PCDD/F value of 1.16 ng WHO-TEQ/kg was 0.5 portion of 227 g (at a risk limit of 1:100,000), which corresponds to the average canned fish consumption in Poland. Variations in the dioxin content in canned fish of different species indicate that one can consume, monthly, without any carcinogenic risk, two portions of 227 g of canned mackerel, while the consumption of canned sprats is not recommended. However, it should be stressed that the problem of the toxicological assessment of dioxins is controversial.

Differences in evaluations of PCDD/Fs and dl-PCB toxicity by scientists from various countries have served to develop the methodology and principles for determining the tolerable limits for the intake of dioxin and furans and dioxin-like PCBs, as well as the impact of these compounds on human health. International evaluation was recently discussed at an EFSA meeting (EFSA, 2004), and it was determined that, although opinions regarding dioxin toxicity are generally in agreement, the differences in risk assessment and the interpretation of data both require further study.

In reference to the recommendations of EFSA experts to the WHO-International Programme on Chemical Safety, toxic equivalency factors (TEF) were reevaluated for some dioxin and dioxin-like PCB congeners. Based on the results of tests and the reevaluation conducted, they estimated that, for example, the total TEQ level for Baltic herring, in comparison to the TEQ determined based on the TEF from 1998, decreased by about 25% (Van den Berg et al., 2006).

An analysis of the world literature leads to the conclusion that most publications indicate that the benefits of consuming fish outweigh the potential risk of contracting cancer associated with presence of PCDD/Fs. A study of over 60,000 women between the ages of 40 and 76, conducted in Sweden, indicated that the risk of contracting kidney cancer was 74% lower in women who ate fat fish at least once per week for a period of ten years than it was in women who did not eat fish (Wolk, Larsson, Johansson, & Ekman, 2006).

Reports on farmed salmon by Santeree (2004), Santeree (2004a) maintain that the regular consumption of 227 g of salmon weekly for 70 years increases the risk of contracting cancer (for the entire American population of 300 million) by 0.002%. By contrast, this type of diet decreased the risk of sudden death from coronary disease by 20% to 40%. According to calculations by the AHA, this impacts from 50,000 to 100,000 Americans. In order to reduce the risk of sudden death caused by coronary disease, it is recommended to consume the fatty acids EPA and DHA in quantities of about 1 g/day. Mozaffarian and Rimm (2006) reached similar conclusions, reporting that consuming fish (1–2 portions/week) rich in the acids EPA and DHA reduces the risk of death associated with heart disease by 36% and overall mortality by 17%. Ingesting approximately 250 mg of EPA and DHA appears to be sufficient amount for basic prophylaxis. These authors maintain that the benefits from fish consumption outweigh the possible risks associated with dioxins and polychlorinated biphenyls. This applies to nursing mothers as well, provided they consume selected fish species.

An analysis of the preceding report leads to the conclusion that the canned fish products available on the Polish market, which contain an average of 1120 mg/100g of EPA and DHA, might be a good source of fatty acids that have a prophylactic effect on heart disease.

Due to the contents of omega-3 fatty acids, the products available on the Polish market can be counted among those that are rich in EPA and DHA (as little as 45 g of canned product contains the recommended daily intake of these acids for reducing the risk of heart disease). The benefits of consuming fish and fish products also stem from the nutritional value, especially of the protein, which is of high biological quality, vitamins D, A, and B_{12}, iodine, and selenium. Fish are particularly important sources of iodine and selenium.

However, due to the potential carcinogenic risk of the dioxin and dl-PCB contained in fish and fish products, the Polish public is informed of both the benefits and the possible risks of consuming fish. Consumer information, for instance, recommends that pregnant and nursing women avoid some species of fish that have elevated levels of dioxin and dl-PCB.

Fat-soluble contaminants, such as dioxin and dl-PCB, are also found in other foodstuffs, especially those with high fat content. Consumers can also exceed the PTWI for dioxin and dl-PCBs independently of whether or not they ingest fish. This is why limiting fish consumption in favour of meat does not actually lead to less exposure to the effects of these compounds.

Although there is wide-ranging acceptance within the scientific community of the principles for determining guidelines for basic health, the interpretation of results of such evaluations can differ significantly, depending on the policies of national authorities (EFSA, 2005).

The current study is the first of a two-part study of fish products available on the Polish market. It focussed on canned fish, the consumption of which is low in Poland at an annual average of approximately 1.5 kg per capita. The second publication will present results from other varieties of processed fish products, including salted, smoked, and marinated fish.

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