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Content of essential polyunsaturated fatty acids in three canned fish species

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Abstract
Three canned fish species—Pacific saury (*Cololabis saira*), Pacific herring (*Clupea harengus*) and Baltic sprat (*Sprattus sprattus*)—most common and popular in Russia, were analyzed for fatty acids. Special attention was paid to long-chain essential polyunsaturated fatty acids: eicosapentaenoic acid (20:5ω3) and docosahexaenoic acid (22:6ω3). Sums of eicosapentaenoic acid and docosahexaenoic acid in saury, herring and sprat were, on average, 2.42, 1.80 and 1.43 g/100 g product, respectively. Contents of these essential acids in all the canned fish species were found to be very high compared with many other fish reported in the available literature. All the canned fish appeared to be highly valuable products for human nutrition concerning the content of eicosapentaenoic and docosahexaenoic acids.

Keywords: *Essential polyunsaturated fatty acids, canned fish, saury, sprat, herring*

Introduction

In past decades, dietary polyunsaturated fatty acids (PUFAs) were widely recognized to generally support human health. PUFAs of the ω3 family, especially eicosapentaenoic acid (20:5ω3, EPA) and docosahexaenoic acid (22:6ω3, DHA), became known as key dietary nutrients for preventing mental, neural and, especially, cardiovascular diseases; and thus many international and national organizations (World Health Organization, British Nutrition Foundation, The American Heart Association, etc.) have recommended daily consumption of about 1 g EPA+DHA in the human diet (for example, Arts et al. 2001; Foran et al. 2005; Garg et al. 2006). The long-chain PUFAs EPA and DHA are efficiently synthesized *de novo* only by a number of microalgae species, which are subsequently consumed by aquatic invertebrates and fish; thereby, aquatic foods are known to be the main source of PUFA-accumulated products for humans (Arts et al. 2001).

Since the consumption of raw fish is rare in western societies (Candela et al. 1998), fish products are prepared by heating and other culinary treatments. However, the long-chain PUFAs are considered highly susceptible to oxidation, and an exposure to high temperatures and air during processing and storage can cause deterioration of

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these fatty acids in foods (Candela et al. 1998; Sant'Ana and Mancini-Filho 2000; Chaijan et al. 2006; Garg et al. 2006; Sampaio et al. 2006; Sioen et al. 2006; Estevez et al. 2007). Nevertheless, recent evidence indicated that the oxidation of PUFAs did not occur in a number of stored and heated fish products (Candela et al. 1998; Echarte et al. 2001; Montano et al. 2001; Gladyshev et al. 2006, 2007; Stolyhwo et al. 2006; Haak et al. 2007; de Castro et al. 2007; Yanar et al. 2007). Canned fish and other canned aquatic organisms are also popular products, but data on their PUFA composition are comparatively scarce (Sanchez-Machado et al. 2004; Tarley et al. 2004).

Thereby, the goal of our study was to determine the content of PUFAs in several kinds of canned fish, most common and popular in Russia.

Materials and methods

Canned fish samples

Three canned fish species were sampled: Pacific saury (*Cololabis saira*), Baltic sprat (*Sprattus sprattus*) and Pacific herring (*Clupea harengus*). All species were represented by one kind of product; that is, they were all canned in sunflower oil. Each canned species was produced by one firm. The canned fish were purchased in five supermarkets of Krasnoyarsk city (Siberia, Russia) abbreviated below by different letters (a, b, c, d, k, following the first letter in the supermarket name). The purchasing of samples in different supermarkets was intended to average possible differences in storage conditions and shelf-life spans. In each supermarket, three cans of each species were purchased. Sprat and herring were purchased in three supermarkets, thus nine replicated samples of each species were analyzed. Saury was purchased in two supermarkets, and thereby six cans were analyzed as replicates.

Three subsamples from each can were taken, homogenized and pooled. A portion of the pooled sample of about 0.3–0.5 g was taken for fatty acid analyses. The rest of the sample of about 10–15 g was used for moisture measurements and dried until constant weight at 105°C.

Analysis

Lipid extraction and formation of fatty acid methyl esters (FAMEs) techniques, and subsequent analysis using gas chromatography–mass spectrometry (GC-MS) of FAMEs, were the same as in our previous work (Gladyshev et al. 2006). Briefly, the extraction of lipids from samples was carried out using chloroform:methanol mixture (2:1, v/v). The extractions of each sample were done three times simultaneously with mechanical homogenization of the tissues. A fixed volume of an internal standard solution (19:0) was added to the samples prior the extraction. FAMEs were prepared in a mixture of methanol–sulfuric acid (20:1, v/v) at 90°C for 2 h. FAMEs were then analyzed using GC-MS (model GCD Plus; Hewlett Packard, La Jolla, CA, USA) equipped with a 30 m long $\times$ 0.32 mm internal diameter capillary column (HP-FFAP Agilent, La Jolla, CA, USA). Peaks of FAMEs were identified by their mass spectra, comparing with those in the database (Hewlett-Packard) and with those of available authentic standards (F.A.M.E. Mix C4-C24, catalogue number 18919-1AMP; Supelco-Sigma, Bellefonte, PA, USA). To determine the positions of double bonds in monoenoic and polyenoic acids, GC-MS of dimethyloxazoline derivatives of fatty acids was used (Makhutova et al. 2003).

Statistics

Calculations of standard errors, Student's *t*-test and one-way analysis of variance (ANOVA) were carried out conventionally (Campbell 1967). To compare the total fatty acid composition as a multi-dimensional characteristic of samples, one-linkage cluster analysis was carried out in the conventional way (Jeffers 1981), using Euclidean distances. Calculations were carried out using STATISTICA software (version 6.0; StatSoft Inc., Tulsa, OK, USA).

Results

The average moisture contents of canned herring, sprat and saury were $64.6 \pm 0.8\%$, $60.8 \pm 1.6\%$ and $59.2 \pm 1.4\%$, respectively. The moisture contents of herring according to Student's *t*-test were significantly higher than those of sprat and saury: *t* values were 2.12 and 3.35, $P < 0.05$ and $P < 0.01$ for degrees of freedom 16 and 13, respectively.

In all samples, 49 fatty acids were identified. The contents of quantitatively prominent fatty acids are presented in Table I. Cluster analysis carried out for the overall fatty acid contents (Figure 1) revealed no influence of supermarket type, and no significant differences between herring and Pacific saury, while sprat samples tended to separate into one distinct cluster. One-way ANOVA carried out for the prominent acids (Table I) revealed that the differences between herring and saury, on the one hand, and herring and sprat, on the other, were primarily due to a higher content of oleic acid (18:1ω9), linoleic acid (18:2ω6) and linolenic acid (18:2ω3) and also due to a lower content (absence) of 20:1 and 22:1 acids in sprats.

The sum of the EPA and DHA contents (Figure 2) of saury was significantly higher than those of sprat (*t*-test, *t* value = 2.72, degrees of freedom = 13, $P < 0.05$). There were no significant differences in EPA + DHA content (wet weight) between saury and herring, or between herring and sprat.

Using the data of Figure 2, the quantity of the canned products that can provide the officially recommended appropriate daily intake of EPA + DHA of 1 g per person was calculated. The recommended daily quantity of the sum of EPA and DHA acids is contained in 41 g canned saury, 55 g canned herring and 70 g canned sprat.

Discussion

From a nutritional point of view, the contents of the essential ω3 fatty acids in all these canned fish species were high. Sums of EPA and DHA in saury, herring and sprat were 5.98, 5.04 and 3.57 g/100 g dry weight on average, respectively (Table I and Figure 2). These values were about two to three times higher than those for fresh dorsal muscles of rainbow trout (Kainz et al. 2004). It is important to remark that in terrestrial animal products the contents of EPA and DHA were several hundred times lower than in the canned fish. For instance, in a Thai fermented pork sausage, the content of the essential acid DHA was only 0.01 g/100 g dry weight, and EPA was not detected at all (Visessanguan et al. 2006).

Table I. Fatty acid concentrations (g/100 g dry weight) of Pacific saury (*Cololabis saira*), Baltic sprat (*Sprattus sprattus*) and Pacific herring (*Clupea harengus*) in canned fish.

Fatty acid	Saury	Sprat	Herring	Sum of squares	Variance explained (%)	Fisher's test *F*
14:0	2.34±0.26	0.60±0.11	2.37±0.24	24.4	**71.4**	23.71
15:0	0.22±0.03	0.09±0.01	0.12±0.01	0.1	**60.4**	14.50
16:0	3.81±0.36	5.34±0.71	4.52±0.50	66.4	13.0	1.42
16:1ω7	1.16±0.16	1.00±0.13	1.65±0.33	11.7	17.3	1.99
16:1ω6	0.13±0.02	0.04±0.01	0.17±0.08	0.6	14.9	1.66
i17:0	0.15±0.02	0.05±0.01	0.09±0.01	0.1	48.6	8.98
17:0	0.10±0.01	0.07±0.01	0.12±0.03	0.1	11.2	1.20
16:4ω1	0.10±0.02	0.02±0.00	0.13±0.02	0.1	**55.4**	11.80
18:0	0.68±0.06	1.06±0.15	0.95±0.22	5.8	8.9	0.93
18:1ω9	1.49±0.15	6.76±0.91	4.92±0.66	192.0	**52.2**	10.39
18:1ω7	0.32±0.03	0.44±0.11	0.44±0.10	1.7	3.7	0.37
18:1ω5	0.18±0.03	0.00±0.00	0.02±0.02	0.2	**76.4**	30.83
18:2ω6	1.13±0.28	9.41±1.13	4.17±0.78	405.7	**65.9**	18.35
18:3ω6	0.04±0.01	0.01±0.00	0.03±0.00	0.0	**66.4**	18.81
18:3ω3	0.45±0.05	1.54±0.16	0.19±0.03	11.1	**81.4**	41.51
18:4ω3	1.38±0.15	0.29±0.04	0.55±0.07	5.7	**78.1**	33.80
18:4ω1	0.04±0.01	0.00±0.00	0.06±0.01	0.0	**56.5**	12.36
20:0	0.02±0.01	0.07±0.01	0.05±0.01	0.0	32.1	4.49
20:1[a]	4.13±0.52	0.09±0.01	2.53±0.21	73.7	**85.0**	53.68
20:4ω6	0.15±0.02	0.11±0.01	0.09±0.01	0.0	49.8	9.42
20:4ω3	0.33±0.03	0.10±0.02	0.15±0.01	0.3	**69.3**	21.43
20:5ω3	2.12±0.32	1.23±0.14	2.30±0.31	17.1	33.4	4.76
22:0	0.00±0.00	0.09±0.01	0.03±0.01	0.1	**62.7**	16.00
22:1[a]	5.31±0.93	0.00±0.00	3.02±0.31	139.0	**76.3**	30.60
21:5ω3	0.12±0.02	0.02±0.00	0.11±0.03	0.1	42.3	6.95
22:5ω3	0.45±0.05	0.12±0.02	0.16±0.01	0.6	**78.0**	33.77
22:6ω3	3.86±0.45	2.34±0.28	2.74±0.35	29.2	29.3	3.93
Total[b]	31.08±3.40	31.53±3.76	32.39±3.05	2041.9	0.3	0.03
Sum ω3[b]	8.82±1.01	5.74±0.64	6.23±0.74	136.2	27.5	3.60
Sum ω6[b]	1.66±0.29	9.72±1.15	4.56±0.84	404.0	**63.2**	16.31

Data presented as mean values from six (saury) and nine (sprat and herring) samples ± standard error, and results of one-way ANOVA comparing fatty acids concentrations of the three canned fish. Between-level and residual degrees of freedom are 2 and 21, respectively. Values explaining more than 50% of variances are reported in bold. [a]ω11+ω9. [b]For 49 acids.

Taking the wet weight into consideration, contents of EPA+DHA in saury, herring and sprats were 2.42, 1.80 and 1.43 g/100 g wet weight, respectively (Figure 2). These values were similar to those of pan-fried Atlantic salmon (Sioen et al. 2006), but were four or five times higher than those of pan-fried cod (Sioen et al. 2006), five to seven times higher than those for fresh filets of gilthead and white sea bream (Ozyurt et al. 2005), about 10–30 times higher than those for edible Thai aquatic insects (Yang et al. 2006), about 20–30 times higher than those for quail eggs (Tokusoglu 2006), and about 40–50 times higher than those for two abalone species (Su et al. 2006). In pan-fried pork, the EPA+DHA content was reported to be 0.03 g/100 g (Haak et al. 2007).

The EPA+DHA contents in the canned fish species were higher, both per wet weight and per dry weight, than those of several other fish species, which were studied as fresh, unfrozen and cooked (Gladyshev et al. 2006, 2007; Sushchik et al. 2007),

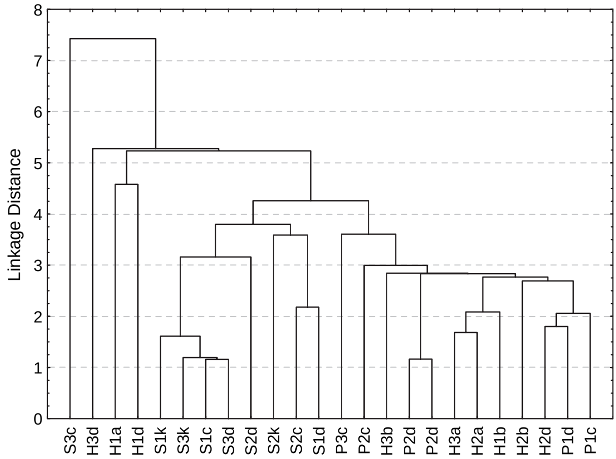

Figure 1. Dendrogram of the cluster analysis of 49 fatty acid concentrations (g/100 g dry weight) in canned fish samples. S, sprat; H, herring; P, Pacific saury; numerals, number of samples; small letters, abbreviations of supermarkets. The ordinate axis represents Euclidean distances in 49-dimensional hyperspace.

including Pacific herring. Similarly, an enhancing of PUFA concentrations during pan-frying pork (Haak et al. 2007) and pan-frying cod (Sioen et al. 2006) was also reported. The latter authors argued that such increase in EPA and DHA concentrations in cod could only be explained by moisture loss during frying. Indeed, we previously found that unfrozen Pacific herring had high moisture contents of 73.9 $\pm$ 1.8% (Gladyshev et al. 2007), while in this study the canned Pacific herring moisture was less (64.6 $\pm$ 0.8% on average). Another possible cause of higher EPA and DHA concentrations in canned fish may be a difference in sampled portions of the fish. In previous studies (for example, Gladyshev et al. 2007) we conventionally sampled dorsal muscle tissues (fillets), while in the present study the analyzed samples also included ventral parts. The ventral parts of some fish species were recently reported to have the higher amounts of EPA+DHA compared with other parts (Palmeri et al. 2007). However, other authors found no differences in the EPA and DHA contents between ventral and dorsal muscles of some fish (Mnari et al. 2007).

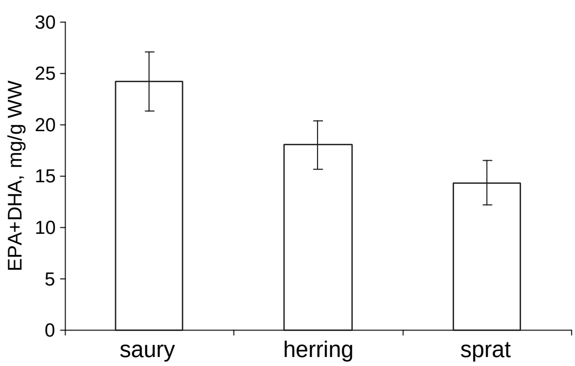

Figure 2. Sum of the EPA and DHA concentrations (mg/g wet weight) in canned fish. Mean values from six samples for saury and from nine samples both for herring and sprat. Bars represent standard errors.

In contrast to our data, some authors reported lower EPA and DHA levels in canned fish compared with raw fish (Tarley et al. 2004). It should be noted that in the cited work relative PUFA values (% of total reported FAME) were reported, rather than absolute values (per unit sample mass) as used in this study. Consequently, relative values instead of absolute values may cause misleading conclusions. For instance, in our previous study cod was found to have the highest percentage level of EPA + DHA among four fish species, while the mass content of these PUFAs (g/100 g product) in cod appeared to be the lowest (Gladyshev et al. 2007).

Conclusions

In summary, it can be concluded that contents of these essential fatty acids (EPA and DHA) in these canned fish species were very high compared with those in many other fish reported in the literature. Thereby, canned Pacific saury, Pacific herring and Baltic sprat are highly valuable products for human nutrition concerning eicosapentaenoic acid and docosahexaenoic acid contents.

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