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NUTRITIONAL COMPOSITION OF FROZEN FILLETS FROM PANGASIUS CATFISH (*PANGASIUS HYPOPHTHALMUS)* AND NILE TILAPIA *(OREOCHROMIS NILOTCUS)* IMPORTED TO EUROPEAN COUNTRIES*

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Abstract

The proximate composition, fatty acids and amino acids profile as well as mineral composition of frozen fillets from Pangasius catfish (*Pangasius hypophthalmus*) imported to Poland (PP), Germany (PG) and Ukraine (PU) and fillets from Nile tilapia (*Oreochromis nilotcus*) imported to Poland (TP) and Germany (TG) were investigated. PU contained ten times more fat than PG and PP. Tilapia fillets contained higher levels of *n-3* fatty acids and showed more preferable *n-6/n-3* ratio than pangasius fillets. The fillets of PG contained higher levels of protein and essential amino acids than PU and PP, however the amino acids composition of pangasius and tilapia fillets was similar for all specimens. The fillets of PP and PU contained significantly higher amounts of sodium than other studied groups, which suggests that they were subjected to additional treatment to increase their water holding capacity. The results show significant differences in the nutritional composition of pangasius depending on their place of import, thus it was recommended that more information regarding the nutritional composition of the frozen fillets sold through self-service freezers should be provided for the final consumer.

Key words: pangasius, tilapia, amino acids, fatty acids, minerals

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Abbreviations:
ALA – alpha linoleic acid
DFA – neutral or hypocholesterolemic fatty acids
DHA – docosahexaenoic acid
DPA – docosapentaenoic acid
EPA – eicosapentaenoic acid
MUFA – monounsaturated fatty acids
OFA – hypercholesterolemic fatty acids
PG – Pangasius imported to Germany
PP – Pangasius imported to Poland
PU – Pangasius imported to Ukraine
PUFA – polyunsaturated fatty acids
SFA – saturated fatty acids
TG – Tilapia imported to Germany
TP – Tilapia imported to Poland
UFA – unsaturated fatty acids

Nutritional value of fish meat is widely appreciated by the consumers. Fish meat is a source of proteins rich in essential amino acids, contains usually high amounts of omega-3 fatty acids and provides many other nutrients such as fat soluble vitamins and micro- and macroelements. Due to this the demand for fish meat is growing constantly. On the other hand the global supply of fish and seafood decreases (Brunner et al., 2009). This led to increased interest in aquaculture and fish farming.

The production of fish and seafood from aquaculture has been growing since the 1970s and currently accounts for around 50% of world fish and seafood supply. Pangasius catfish (*Pangasius hypophthalmus)* and Nile tilapia (*Oreochromis niloticus)* are one of the most important farmed species, with increase in production rate during the last 10 years of 220.1% and 22.2%, respectively (Bostock et al., 2010). Despite the growing popularity, there is still little data regarding the content of important quality nutritional components of frozen fillets from pangasius and tilapia such as micro- and macroelements and amino acids composition.

Health benefits of *n-3* fatty acids consumption are well studied. Research showed that they can have a protective role in cardiovascular diseases, show anti-cancerogenic and anti-inflammatory properties, influence the proper functioning of the eye, are crucial at an early stage of neurodevelopment and have a protective role in neurodegenerative diseases (Calder, 2012).

Recently there is a growing concern over declining amount of micro- and macroelements in grains, fruits and vegetables, attributed mostly to improved crop yields and more effective production techniques over last decades. Those declining micro- and macronutrients include Ca, Fe and Mg (Davis, 2009). One of the proposed methods to deal with this problem is to increase the diet diversity (Fan et al., 2008) and fish and seafood were reported as a good source of those nutrients (Poławska et al., 2011; Jodral-Segado et al., 2003). Due to this it is important to know the amount of minor and major elements in frozen fillets from pangasius and tilapia, which are one of the most popular freshwater fish species consumed in many countries.

Not many fish species received so much attention from the media as Pangasius catfish. Due to a number of negative marketing actions, which include TV documentaries and listing this fish on the Red List of the World Wide Fund for Nature (Little et al., 2012), the fish image has become controversial, which seems supported by our previous research on a group of Polish consumers, even though we have shown that most of the allegations are completely unfounded (Kulawik et al., 2015 b; Kulawik et al., 2015 a).

In order to establish the nutritional composition of frozen fillets from pangasius and tilapia a study was designed to determine the proximate composition, fatty acids, amino acids and mineral contents of frozen fillets from Pangasius catfish (*Pangasius hypophthalmus)* and Nile tilapia (*Oreochromis niloticus)*, imported to Poland, Germany and Ukraine.

Material and methods

Materials

Twenty-five frozen skinless fillets from Pangasius catfish and 25 frozen skinless fillets from Nile tilapia imported to Poland (PP and TP, respectively) were obtained in October 2012, from three different retailers located in Kraków, Poland. Fillets were stored in freezers belonging to the retailer and packed by the self-service method into clean and sterile plastic bags. Immediately after purchase fillets were transported to the freezers located in the Food Technology Department of the University of Agriculture in Cracow and stored at –18°C until further analysis.

Twenty-five frozen skinless fillets from Pangasius catfish and 25 frozen skinless fillets from Nile tilapia imported to Germany (PG and TG respectively) were obtained in September 2012, from four different retailers located in Berlin, Germany. Fillets were packed by the producer and stored in freezers belonging to the retailer. Twenty-five frozen skinless fillets from Pangasius catfish imported to Ukraine (PU) were obtained in October 2012, from three retailers located in Lviv, Ukraine. Fillets were stored in open freezers belonging to the retailer and packed using a self-service method, into clean and sterile plastic bags. No analysis was performed on frozen fillets from Nile tilapia imported to Ukraine because no such fillets were available at the time of purchase.

Immediately after purchase frozen fillets from Germany and Ukraine were transported to the freezers located in the Food Technology Department of the University of Agriculture in Cracow and stored at –18°C until further analysis. During transport fillets were stored in icebox filled with ice bags. After transportation, the temperature of fillets was measured to ensure that it did not exceed –10°C and that the fillets were still fit for analyses.

All purchased pangasius fillets were cultivated and produced in Vietnam, and all purchased tilapia fillets were cultivated and produced in China. According to the ingredients list on the commercial labels, the frozen fish fillets from PG and TG contained fish fillets and water; samples from PU and PP contained fish fillets, water and

polyphosphates (E452) and samples from TP contained fish fillets, water and sodium triphosphate (E451).

All samples were thawed in room temperature, ground and homogenized (each fillet as a separate sample) prior to analysis.

Proximate composition

Ash, protein (Kjeldahl method), fat (Soxhlet method) and dry weight content were performed in accordance with methods of AOAC (2007). The proximate composition was performed on 10 fillets from each group using duplicate repetitions (10 n × 2 for each group).

Fatty acids analysis

Lipids were extracted from muscle samples with chloroform-methanol (2:1) mixture, according to the method described by Folch et al. (1957). So prepared fatty acid methyl esters (FAME) were separated by gas chromatography using Trace GC Ultra gas chromatograph (Thermo Electron Corporation, Waltham, USA) equipped in Supelcovax 10 column (30 m × 0.25 mm × 0.25 μm; Sigma-Aldrich, St. Louis, USA) and flame ionization detector. The carrier gas used was helium with 5 ml/min flow rate. The sample flow rate from the injector was 10 ml/min. The temperatures used were 220°C on the injector, 200°C on the column and 250°C on the detector. Initial column temperature was 160°C. Samples were injected along with the set of standards (Sigma-Aldrich, St. Louis, USA) containing different FAMEs.

Fatty acids profile analysis was performed on 10 fillets from each group using triplicate repetitions (10 n × 3).

Amino acids composition

The analysis of amino acids composition was performed according to AOAC method 994.12 (AOAC, 2007) with ion-exchange chromatography. The samples were hydrolyzed in 110°C in 6M HCl (for asparagine, threonine, serine, glutamic acid, proline, glycine, alanine, valine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine, arginine). Hydrolyzate was evaporated using RVO 200A evaporator (Ingos, Prague, Czech Republic) and dissolved in pH 2.2 buffer. Sulfurous amino acids (methionine and cysteine) were determined by hydrolysis with formic acid and perhydrol. The liquid chromatography separation was performed using AAA-400 amino acids analyzer (Ingos, Prague, Czech Republic) equipped with ion-exchange column and postcolumn ninhydrin derivatization. Buffers and split parameters were used according to guidelines provided by the producer.

The analyses were performed on 4 fillets from each group, using duplicate repetitions (4 n × 2 for each group).

Micro- and macroelements analysis

For analysis of chromium, nickel, copper, iron, zinc, manganese, calcium, phosphorus, magnesium, sodium and potassium, the fish fillets were homogenized and dried in a dryer in 105°C for 24 hours. Afterwards 0.5 g of dried sample was mineralized with concentrated HNO_3 and 30% HCl (Suprapur, Merck KGaA, Darmstadt,

Germany). Mineralization was performed in microwave oven (Anton Paar, Graz, Austria), in 1400 W (reaching time 10 minutes, holding for 20 minutes, cooling for 15 minutes). The further analyses were performed using the Inductively Coupled Plasma (ICP) on the Perkin-Elmer ICP-OES 7300 Dual View apparatus (Perkin-Elmer, Waltham, USA). Wavelengths, detection limits for individual elements are shown in Table 1. The acquired results were calculated and presented as mg of element in kg of fish fillet.

Table 1. Wavelengths and detection limits for individual elements measured by ICP

Element	Wavelength (nm)	Detection limit (mg/l)
Fe	238.204	0.0046
Zn	206.200	0.0059
Ni	231.604	0.0150
Cu	327.393	0.0097
Mn	257.610	0.0014
Cr	267.716	0.0071
Ca	317.933	0.0100
Mg	285.208	0.0016
Na	589.592	0.0690
P	213.617	0.0760
K	766.490	0.0090

The analysis was performed on 6 fillets from each group using duplicate repetitions. On each repetition, 3 analyses were performed on IPC apparatus (6 n × 2 × 3 for each group).

After acquiring results of sodium analysis, an additional analysis for sodium chloride content was performed. The NaCl determination was performed using Mohr method according to Kirk et al. (1991). Acquired results were calculated and presented as g of NaCl/kg of fish fillet. The analysis of sodium chloride was performed on 5 fillets from each group using duplicate repetitions (5n × 2 for each group).

Statistical analysis

The statistical analysis was performed using Statistica software (StatSoft, Tulsa, USA). The normality of results and homogeneity of variances were calculated using the Shapiro-Wilk and t-test. Variables with normal distribution and uniform variances were calculated by one-way ANOVA and the significance of differences was established using Tukey post-hoc test. For variables without normal distribution or uniform variances, the significance of differences was calculated using nonparametric Kruskal-Wallis ANOVA, with multiple ranks comparison test. The analysis of significance of differences was performed separately for pangasius and tilapia fillets imported to different countries. Significance of difference was established for $P=0.05$ (the null hypothesis was discharged for $P<0.05$). The results were labeled using a, b, c letters, where results with different letter differ significantly from each other ($P<0.05$). The significance of each ANOVA is shown in Table 2.

Table 2. The significance of ANOVA for each studied parameter

Parameter	Significance (p) of ANOVA for pangasius groups	Significance (p) of ANOVA for tilapia groups
1	2	3
Proximate composition		
Dry weight	<0.001	0.053
Fat	<0.001	0.010
Protein	<0.001	0.001
Ash	<0.001	0.173
Fatty acids		
C10:0	0.792	0.102
C12:0	<0.001	0.275
C14:0	0.012	0.135
C14:1	<0.001	0.284
C15:0	0.659	0.102
C16:0	0.455	0.649
C16:1*n-9*	0.140	0.318
C16:1*n-7*	0.058	0.676
C17:0	0.346	0.388
C17:1	0.060	0.490
C18:0	0.653	0.469
C18:1*n-9*	0.491	0.314
C18:1*n-7*	0.697	0.685
C18:2*n-6*	0.401	0.695
C18:3*n-6*	0.479	0.733
C18:3*n-3*	0.807	0.955
C18:3*n-4*	0.497	0.894
C20:0	0.025	0.746
C20:1*n-9*	0.652	0.688
C20:2*n-6*	0.762	0.844
C20:3*n-6*	0.515	0.652
C20:4*n-6*	0.403	0.907
C20:5*n-3*	0.065	0.173
C22:1	0.635	0.278
C22:5*n-3*	0.555	0.955
C22:6*n-3*	0.384	0.165
SFA	0.152	0.517
UFA	0.011	0.234
MUFA	0.664	0.657
PUFA	0.255	0.209
PUFA *n-6*	0.020	0.297
PUFA *n-3*	0.696	0.517
n-6/n-3	0.118	0.467
UFA/SFA	0.015	0.543
PUFA/SFA	0.008	0.516
PUFA/MUFA	0.006	0.440
OFA	0.221	0.615
DFA	0.015	0.075
DFA/OFA	0.281	0.674

Table 2 – contd.

1	2	3
Thr	<0.001	0.537
Val	<0.001	0.268
Ile	<0.001	0.020
Leu	<0.001	0.005
Phe + Tyr	<0.001	0.074
Lys	<0.001	0.006
Met + Cys	0.003	0.527
His	<0.001	0.383
Arg	<0.001	0.075
Asp	<0.001	0.003
Ser	<0.001	0.161
Gly	<0.001	0.071
Glu	<0.001	0.003
Ala	<0.001	0.024
Pro	<0.001	0.067
Amino acids composition of protein		
Thr	0.359	0.092
Val	0.554	0.641
Ile	0.831	0.508
Leu	0.754	0.267
Phe + Tyr	0.054	0.875
Lys	0.714	0.341
Met + Cys	0.556	0.513
His	0.286	0.052
Arg	0.401	0.985
Asp	0.850	0.113
Ser	0.635	0.143
Gly	0.423	0.388
Glu	0.206	0.979
Ala	0.997	0.841
Pro	0.610	0.688
Minor elements		
Zn	0.809	0.345
Ni	<0.001	0.161
Mn	0.708	0.966
Fe	0.306	0.087
Cu	0.052	0.188
Cr	0.614	0.480
Major elements		
Mg	<0.001	0.007
Ca	0.086	0.100
Na	<0.001	<0.001
K	<0.001	0.144
P	<0.001	0.337
NaCl	<0.001	0.168

Results

The results of proximate composition analysis are shown in Table 3. The most significant differences between studied groups were found in fat content. Pangasius imported to Ukraine showed more than 10 times higher levels of fat than pangasius imported to Poland and Germany. Moreover, PU also showed significantly higher levels of dry weight than other pangasius groups. The dry weight content of frozen tilapia fillets did not differ significantly between studied groups. The protein content was the highest in fish fillets imported to Germany. The ash content of PG was generally more similar to frozen fillets from tilapia and was significantly lower than of PP and PU. There were significant differences in protein and fat content between studied tilapia groups, with TP having more fat and lower protein.

Table 3. Proximate composition of frozen fillets from Pangasius catfish and Nile tilapia (% of fish fillet)

	Dry weight (P<0.001)	Fat (P<0.001)	Protein (P<0.001)	Ash (P<0.001)
PP	16.53±0.501 a	1.05±0.20 a	11.99±0.28 a,b	1.35±0.10 b
PG	19.7±0.27 b	0.83±0.04 a	16.75±0.18 b	0.8±0.04 a
PU	23.12±0.95 c	10.8±1.09 b	11.12±0.30 a	1.43±0.08 b
TP	17.51±0.63	1.9±0.18 b	15.92±0.35 a	0.91±0.02
TG	19.57±0.61	1.4±0.10 a	17.81±0.23 b	0.85±0.01

Results expressed as means ± standard error of the mean.
a, b, c – significance of differences for P<0.05.

The fatty acids composition of both Pangasius catfish and Nile tilapia along with calculated quality indicators are shown in Table 4. The fatty acids composition of tilapia fillets imported to different European countries did not differ significantly from each other. Similar results were acquired for pangasius fillets with the exception of higher content of C14:1 in PU than in other pangasius groups. The content of oleic acid (C18:1 *n-9*) in pangasius was almost two times higher than in studied tilapia groups, which is the main reason for higher MUFA content in pangasius groups.

The most abundant *n-3* fatty acids present in pangasius fillets were ALA followed by DHA, DPA and EPA while tilapia contained mostly DHA followed by ALA, DPA and EPA. PP had significantly higher levels of *n-6* fatty acids then PG and higher overall content of UFA than PG and PU. It also showed significantly higher ratios of UFA/SFA, PUFA/SFA, and PUFA/MUFA and higher amounts of DFA than PG. No significant differences in fatty acids profile were found within studied tilapia groups.

Table 4. Fatty acids composition of frozen fillets from Pangasius catfish and Nile tilapia (% of fat)

Group	C10:0 (P<0.001)	C12:0 (P<0.001)	C14:0 (P<0.001)	C14:1 (P<0.001)	C15:0 (P<0.001)	C16:0 (P=0.014)	C16:1*n-9* (P<0.001)	C16:1*n-7* (P<0.001)	C17:0 (P=0.004)	C17:1 (P<0.001)	C18:0 (P=0.462)	C18:1*n-9* (P<0.001)	C18:1*n-7* (P<0.001)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
PP	0.014 ±0.002	0.046 a ±0.002	2.623 a ±0.102	0.011 ±0.001 a	0.345 ±0.040	28.294 ±1.432	0.367 ±0.017	0.850 ±0.026	0.265 ±0.018	0.076 ±0.004	8.887 ±0.373	40.134± 1.160	0.672± 0.060
PG	0.017 ±0.002	0.112 b ±0.010	2.927 ab ±0.098	0.011 ±0.001 a	0.564 ±0.062	28.825 ±0.818	0.317 ±0.017	0.977 ±0.031	0.291 ±0.006	0.066 ±0.003	8.782 ±0.286	39.756± 0.551	0.732± 0.055
PU	0.014 ±0.002	0.131 b ±0.014	2.992 b ±0.068	0.093 ±0.005 b	0.515 ±0.032	28.847 ±0.293	0.311 ±0.018	0.918 ±0.026	0.269 ±0.019	0.080 ±0.004	8.819 ±0.180	39.033 0.379	0.748± 0.040
TP	0.035 ±0.003	0.725 ±0.032	3.849 ±0.148	0.117 ±0.004	0.230 ±0.007	25.435 ±0.955	0.782 ±0.035	4.142± 0.301	0.372 ±0.043	0.249 ±0.014	8.256 ±0.373	21.481 ±0.677	3.928 ±0.128
TG	0.040 ±0.009	0.683 ±0.046	4.108 ±0.170	0.109 ±0.005	0.265 ±0.020	24.858 ±0.528	0.725 ±0.039	3.803 ±0.133	0.334 ±0.027	0.242 ±0.015	8.150 ±0.174	22.694 ±0.590	3.808 ±0.098
Group	C18:2*n-6* (P<0.001)	C18:3*n-6* (P<0.001)	C18:3*n-3* (ALA) (P=0.002)	C18:3*n-4* (P<0.001)	C20:0 (P=0.082)	C20:1*n-9* (P=0.331)	C20:2*n-6* (P<0.001)	C20:3*n-6* (P<0.001)	C20:4*n-6* (P<0.001)	C20:5*n-3* (EPA) (P<0.001)	C22:1 (P<0.001)	C22:5*n-3* (DPA) (P<0.001)	C22:6*n-3* (DHA) (P<0.001)
PP	10.500 ±0.685	0.317 ±0.020	0.851 ±0.161	n/d	0.201 b ±0.011	1.994 ±0.308	0.400 ±0.019	0.763± 0.062	0.860 ±0.088	0.142 ±0.019	0.293 ±0.065	0.200 ±0.019	0.491 ±0.089
PG	9.238 ±0.429	0.324 ±0.022	0.797 ±0.067	n/d	0.160 a ±0.009	1.864 ±0.161	0.402 ±0.026	0.794± 0.046	0.863 ±0.046	0.199 ±0.016	0.415 ±0.064	0.220 ±0.017	0.766 ±0.061
PU	9.947 ±0.178	0.375 ±0.017	0.901 ±0.036	n/d	0.193 ab ±0.005	1.854 ±0.040	0.385 ±0.019	0.839± 0.038	0.803 ±0.037	0.199 ±0.006	0.363 ±0.018	0.199 ±0.006	0.671 ±0.019
TP	15.136 ±0.859	0.729 ±0.036	1.309 ±0.107	0.104 ±0.027	0.190 ±0.010	1.609 ±0.167	1.020 ±0.067	1.077± 0.063	2.675 ±0.100	0.559 ±0.113	0.086 ±0.008	1.048 ±0.107	3.871± 0.378
TG	14.361 ±0.234	0.715 ±0.020	1.397 ±0.071	0.111 ±0.008	0.195 ±0.008	1.485 ±0.139	1.001 ±0.082	1.092± 0.045	2.809 ±0.101	0.892 ±0.080	0.099 ±0.004	1.145 ±0.077	3.065 ±0.200
Group	SFA	UFA	MUFA	PUFA	PUFA *n-6*	PUFA*n-3*	*n-6/n-3*	UFA/SFA	PUFA/SFA	PUFA/ MUFA	OFA	DFA	DFA/OFA
PP	40.702	58.916 b	44.394	14.522	12.839 b	1.683	7.628	1.447 b	0.357 b	0.327 b	30.945	67.803 b	2.191
PG	41.677	57.737 a	44.136	13.601	11.620 a	1.981	5.866	1.385 a	0.326 a	0.308 a	31.752	66.519 a	2.095

Table 4 – contd.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
PU	41.778	57.716 a	43.398	14.318	12.349 ab	1.970	6.270	1.382 ab	0.343 ab	0.330 ab	31.839	66.535 ab	2.090
TP	39.090	59.918	32.392	27.526	20.637	6.786	3.041	1.533	0.704	0.850	29.284	68.174	2.328
TG	38.632	59.547	32.963	26.585	19.977	6.498	3.074	1.541	0.688	0.807	28.965	67.697	2.337

Results expressed as median±standard error of the mean.

a, b, c – significance of differences for $P<0.05$, n/d – below detection level, SFA – saturated fatty acids, UFA – unsaturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, OFA – hypercholesterolemic fatty acids (C14:0 + C16:0), DFA – neutral or hypocholesterolemic fatty acids (C18:0 + UFA).

Table 5. Amino acids composition and content in frozen fillets from Pangasius catfish and Nile tilapia

	Recommended daily intake for 70 kg human	Egg amino acids content	PP		PG		PU		TP		TG	
	(g/day)[1]	(g/100 g of product)[2]	% of fillet	% of protein	% of fillet	% of protein	% of fillet	% of protein	% of fillet	% of protein	% of fillet	% of protein
Thr (P<0.001)	1.05	0.63	0.54 b	4.9±0.1	0.71 c	4.8±0.1	0.43 a	4.7±0.1	0.68	4.7±0.0	0.71	4.6±0.1
Val (P<0.001)	1.96	0.85	0.58 b	5.2±0.1	0.77 c	5.2±0.1	0.46 a	5.1±0.1	0.74	5.2±0.1	0.79	5.1±0.2
Ile (P<0.001)	1.4	0.78	0.51 b	4.6±0.1	0.67 c	4.5±0.1	0.42 a	4.6±0.0	0.64 a	4.5±0.1	0.71 b	4.5±0.0
Leu (P<0.001)	2.73	1.09	0.93 b	8.4±0.1	1.24 c	8.4±0.0	0.77 a	8.5±0.2	1.17 a	8.2±0.0	1.29 b	8.3±0.1
Phe + Tyr (P<0.001)	1.75	1.22	0.80 a	7.2±0.1	1.13 b	7.6±0.1	0.66 a	7.2±0.1	1.02	7.1±0.1	1.11	7.1±0.3
Lys (P<0.001)	2.1	0.86	1.17 b	10.5±0.3	1.52 c	10.3±0.1	0.96 a	10.6±0.4	1.43 a	10.0±0.1	1.56 b	10.1±0.1
Met + Cys (P<0.001)	1.05	0.72	0.34 a	3.0±0.3	0.51 b	3.5±0.3	0.30 a	3.3±0.4	0.49	3.4±0.2	0.51	3.3±0.0
His (P<0.001)	0.7	0.3	0.29 a	2.6±0.0	0.38 b	2.6±0.0	0.24 a	2.7±0.1	0.47	3.3±0.1	0.45	2.9±0.0
Σ essential	**12.74**	**6.45**	**5.17**	**46.4**	**6.92**	**46.9**	**4.25**	**46.7**	**6.65**	**46.4**	**7.14**	**45.9**
Arg (P<0.001)		0.75	0.84 b	7.6±0.2	1.11 c	7.5±0.1	0.66 a	7.3±0.2	1.08	7.5±0.2	1.17	7.5±0.1
Asp (P<0.001)		1.19	1.26 b	11.3±0.2	1.69 c	11.4±0.2	1.05 a	11.5±0.5	1.61a	11.2±0.1	1.78b	11.4±0.1
Ser (P<0.001)		0.95	0.45 a	4.0±0.1	0.61 b	4.2±0.1	0.38 a	4.2±0.1	0.55	3.8±0.1	0.57	3.7±0.1
Gly (P<0.001)		0.41	0.56 a	5.0±0.1	0.70 b	4.8±0.1	0.45 a	4.9±0.2	0.79	5.5±0.2	0.90	5.8±0.2
Glu (P<0.001)		1.58	1.90 b	17.0±0.2	2.46 c	16.6±0.1	1.52 a	16.7±0.1	2.37 a	16.5±0.1	2.57 b	16.5±0.1
Ala (P<0.001)		0.73	0.60 b	5.4±0.1	0.79 c	5.4±0.0	0.49 a	5.4±0.1	0.83 a	5.8±0.0	0.91 b	5.8±0.0
Pro (P<0.001)		0.51	0.37 a	3.3±0.0	0.48 b	3.2±0.0	0.31 a	3.4±0.1	0.48	3.3±0.1	0.53	3.4±0.1
Σ non-essential		**6.12**	**5.98**	**53.6**	**7.84**	**53.1**	**4.86**	**53.4**	**7.71**	**53.6**	**8.42**	**54.1**
Σ all		12.57	11.15		14.76		9.11		14.36		15.56	

Results expressed as average ± SEM.
a, b, c – significance of differences for P<0.05.
[1]according to FAO (2007), [2]according to FAO (1970).

Table 6. Minor elements in frozen fillets from Pangasius catfish and Nile tilapia (mg/kg of fish fillet)

	PP	PG	PU	TP	TG
			Zn (P=0.763)		
Median	3.612	4.194	3.282	4.463	4.912
SEM	0.470	0.254	0.820	0.288	0.323
Max	5.883	5.258	7.924	4.905	5.764
Min	2.475	3.643	2.266	2.915	3.723
RDI %	3.6	4.2	3.3	4.5	4.9
			Ni (P=0.003)		
Median	0.097 a	0.045 a	0.206 b	0.127	0.056
SEM	0.004	0.007	0.044	0.025	0.002
Max	0.106	0.056	0.249	0.134	0.059
Min	0.091	0.030	0.162	0.029	0.051
RDI %	n/d	n/d	n/d	n/d	n/d
			Mn (P=0.038)		
Median	0.101	0.101	0.097	0.198	0.183
SEM	0.025	0.075	0.023	0.023	0.009
Max	0.233	0.166	0.218	0.222	0.219
Min	0.064	0.075	0.068	0.121	0.156
RDI %	0.5	0.5	0.5	1.0	0.9
			Fe (P=0.260)		
Median	3.791	2.870	2.557	1.840	3.891
SEM	0.842	0.498	0.596	0.526	0.275
Max	5.727	3.364	4.467	4.333	4.381
Min	1.739	1.131	0.613	1.462	3.429
RDI %	2.7	2.1	1.8	1.3	2.8
			Cu (P=0.035)		
Median	0.793	0.423	0.121	0.233	0.308
SEM	0.438	0.091	0.051	0.066	0.035
Max	2.162	0.539	0.283	0.304	0.384
Min	0.182	0.156	0.000	0.000	0.217
RDI %	7.9	4.2	1.2	2.3	3.1
			Cr (P=0.718)		
Median	0.240	0.161	0.322	0.134	0.102
SEM	0.028	0.067	0.100	0.083	0.041
Max	0.307	0.356	0.470	0.591	0.254
Min	0.174	0.039	0.000	0.056	0.073
RDI %	60.0	40.3	80.5	33.5	25.5

Results shown as median of mg of element/kg of fish fillet.

Results marked with different letters (a, b, c) are significantly different ($P<0.05$).

SEM – standard error of the mean.

Max, min – maximal and minimal results acquired from all the results.

RDI % – percentage of human RDI covered by consumption of 100 g of frozen fillet. RDI based on EC (2008).

n/d – no data regarding the RDI for nickel.

Table 7. Major elements in frozen fillets from Pangasius catfish and Nile tilapia (mg/kg of fish fillet)

	PP	PG	PU	TP	TG
			Mg (P<0.001)		
Median	144.9 a	279.6 b	122.9 a	205.0 a	280.7 b
SEM	13.8	12.0	9.3	2.0	14.8
Max	198.5	303.0	157.5	210.3	310.5
Min	94.6	232.5	94.8	200.4	212.5
RDI %	3.9	7.5	3.3	5.5	7.5
			Ca (P=0.064)		
Median	83.6	96.5	108.6	85.1	95.5
SEM	7.7	3.4	23.2	2.7	3.4
Max	100.2	101.6	186.9	94.4	110.4
Min	59.8	77.9	82.8	79.0	89.7
RDI %	1.0	1.2	1.4	1.1	1.2
			Na (P<0.001)		
Median	3765.7 b	320.4 a	5270.3 c	840.3 b	198.0 a
SEM	345.7	32.6	490.8	57.6	22.5
Max	4811.4	384.2	6485.5	1005.2	317.3
Min	2499.0	199.3	3065.0	578.5	165.8
RDI %	25.1	2.1	35.1	5.6	1.3
			K (P<0.001)		
Median	1570 a	3149 b	1579 a	1829	2262
SEM	80	210	130	130	39
Max	1708	3588	1777	2364	2419
Min	1362	2207	1202	1599	2213
RDI %	7.9	15.7	7.9	9.1	11.3
			P (P=0.008)		
Median	1308 a	1816 b	1242 a	1376	1387
SEM	79	105	86	66	29
Max	1589	1861	1601	1407	1486
Min	1108	1227	1049	987	1301
RDI %	18.7	25.9	17.7	19.7	19.8
			Sodium chloride (NaCl)		
Median ± SEM (g of NaCl/ kg of fillet) (P<0.001)	5.8 b±0.4	1.0 a±0.1	5.0 b±0.4	0.8±0.0	0.7±0.1
Na content from NaCl (mg)[1]	2230	380	1930	300	280

Results shown as median of mg of element/kg of fish fillet.

Results marked with different letters (a,b,c) are significantly different (P<0.05).

SEM – standard error of the mean.

Max, min – maximal and minimal results acquired from all the results.

RDI % – percentage of human RDI covered by consumption of 100 g of frozen fillet. RDI for Na based on DHHS (2005) and on EC (2008) for the rest of micro- and macroelements.

[1] – calculated according to Saxholt et al. (2008).

The amino acids content presented as % of the whole fillet and % of protein in frozen fillets from Pangasius catfish and Nile tilapia is shown in Table 5. There were significant differences in the content of all amino acids between pangasius imported to Germany and pangasius imported to Poland and Ukraine, with PG containing the highest levels of all amino acids. Similar findings have been shown when comparing TP and TG with fillets imported to Germany containing significantly higher levels of Leu, Ile, Glu, Ala, Lys and Asp. This is probably due to higher overall content of protein in PG and TG than in other compared groups. In fact the amino acids content of PG resembled more the amino acids content of studied tilapia than pangasius fillets. PP had also significantly higher levels of most amino acids than PU. The analysis showed no significant differences in amino acids composition between studied tilapia groups. The levels of both essential and non-essential amino acids in frozen fillets from the highest to the lowest were TG < PG < TP < PP < PU.

The amino acid composition of protein of pangasius and tilapia frozen fillets shows that there are no significant differences in the protein composition between studied pangasius and tilapia groups.

The content of minor elements in Pangasius catfish and Nile tilapia are shown in Table 6. The content of zinc, chromium, copper, iron, and manganese did not differ significantly between studied groups. The only significant differences were found in the amount of nickel between pangasius groups. The microelements content in tilapia fillets was as follows: Zn > Fe > Cu > Mn > Cr > Ni, while pangasius fillets contained more chromium then manganese: Zn > Fe > Cu > Cr > Mn > Ni. The dispersion range of the results was high within all studied groups and microelements. This, alongside with the lack of significant differences suggests that the content of microelements differs from fillet to fillet rather than from group to group.

The content of major elements is shown in Table 7. PG had significantly different content of macroelements from all other pangasius groups with the exception of calcium. Pangasius fillets imported to Germany had significantly higher levels of phosphorus, magnesium and potassium, while no such differences were noted between PP and PU. TG contained significantly higher levels of Mg than TP. The macroelements content in PU and PP was Na > K > P > Mg > Ca, for PG and TP: K > P > Na > Mg > Ca, while for TG: K > P > Mg > Na > Ca.

The highest differences between studied pangasius groups were noted in sodium content. The results show very high levels of sodium in both PP and PU. Also sodium content in TP was significantly higher than in TG.

The results from sodium chloride analysis are shown in Table 7. The content of NaCl in PP and PU was significantly higher than in PG. The pangasius fillets imported to Poland and Ukraine contained 0.5–0.6% of NaCl while other studied groups contained only around 0.1% NaCl.

Discussion

There were large differences in proximate composition between studied pangasius groups, especially in fat content. The 10 times higher content of fat in pangasius

fillets is most probably due to a strip of belly fat, that was cut off by the producers in PG and PP whereas this fraction remained in PU, which also might resulted in changes of the overall fillet quality. This also explains the higher dry weight content of PU than in all other studied pangasius groups. Unlike PU, the higher dry weight levels in PG than in PP are probably due to higher protein content. The differences in protein content might be a result of different feeding techniques, since Khan et al. (1993) found that fish fed low-protein feeds had lower both growth rate and protein content than fish fed high-protein feeds or the mixture of high-protein and low-protein feeds. Those findings seem to be also true for farmed pangasius (Ali et al., 2005). Alternatively, lower protein content of PP and PU might be a result of some additional treatment of frozen fillets in order to increase its water-holding capacity (WHC) (Sørensen, 2005; Lopkulkiaert et al., 2009). This would increase the water content in fillets, thus reducing the percentage of protein. The dry weight content of frozen tilapia fillets was lower than the dry weight content of fresh tilapia reported by other authors (Emire et al., 2010; Garduño-Lugo et al., 2003).

The lack of differences in fatty acids composition between PU and other pangasius groups is somewhat surprising, due to aforementioned strip of belly fat, which is usually different in fatty acids composition than structural fat present in muscle. The belly fat of fish usually consists of high amounts of neutral lipids, mainly triglycerides the main function of which is energy storage. On the other hand the intra- and intermuscular fats contain both neutral and polar lipids. Polar lipids are composed mostly of phospholipids and are usually associated with higher *n-3* fatty acids content (Weil et al., 2013; Rai et al., 2012). Since the fatty acids in neutral and polar lipids fractions usually differ, it was expected for PU to have significantly different fatty acids composition. Due to this it might be interesting for the future research to study and analyze the fatty acids composition of pangasius from different fat depositions.

Generally the fatty acids composition of tilapia was more desirable than of Pangasius catfish. Tilapia contained higher amounts of PUFA, both *n-3* and *n-6*, lower *n-6/n-3* ratio and more desirable PUFA/MUFA ratio. Moreover, tilapia fat shows higher hypocholesterolemic properties. The fatty acids composition found in this study differs strongly from the fatty acids composition of frozen fillets from Pangasius catfish and Nile tilapia found by Karl et al. (2010) and Usydus et al. (2011). FAO (2010) recommends the daily intake of EPA+DHA at around 0.25–2 g. This recommendation could be covered by the consumption of 1412–11300 g of PP, 1400–11200 g of PG, 112–900 g of PU, 194–1550 g of TP and 275–2200 g of TN.

The *n-6* to *n-3* fatty acids ratio of both Pangasius catfish and Nile tilapia is not desirable, when compared to *n-6/n-3* ratio of different fish species such as sole (0.01–0.37), herring (0.18), rainbow trout (0.23), tuna (0.17), anchovy (0.21), perch (0.11), mackerel (0.10), Baltic salmon (0.13), pollock (0.04), seabream (0.23), crab (0.18) or carp (0.89). Also the overall content of *n-3* fatty acids in fish muscle is usually higher than in frozen fillets from Pangasius catfish and Nile tilapia (Usydus et al., 2011; Sirot et al., 2008; Soriguer et al., 1997; Valente et al., 2011). If fish are to be consumed for nutritional reasons, to improve the *n-3* fatty acids intake, different fish species than tilapia and pangasius should be chosen. Both Pangasius catfish and Nile

tilapia, especially PP and PG, are not good sources of *n-3* fatty acids. Moreover, the dominant *n-3* PUFA in pangasius fillets was ALA, which needs to be further metabolized in our body in order to receive both EPA and DHA, which further decreases the nutritive value of their fat.

Taking into consideration the nutritional value of protein, frozen fillets from tilapia show higher levels of threonine, leucine, histidine and lysine when compared to amino acids composition of hen's egg (FAO, 1970). The high content of lysine makes those fish fillets recommendable for mixing with grain dishes, since lysine is the main limiting amino acid in many grain products. Frozen fillets of pangasius imported to Poland and Ukraine had lower levels of all essential amino acids, with the exception of lysine, than hen's egg. The fact that protein composition within both pangasius and tilapia groups is similar proves that the differences in amino acids content shown in Table 5 were due to different overall protein content of frozen fillets from pangasius rather than the differences in protein itself. This was to be expected since the amino acids composition of fish protein is rather specific for each fish species (Limin et al., 2006).

Tables 6 and 7 summarize the coverage of human Recommended Daily Intake (RDI) of micro- and macronutrients after consumption of 100 g of frozen fillet from pangasius and tilapia. The mineral content of both studied fish species is low and they are not good sources of micro- and macronutrients with the exception of sodium, chromium and phosphorus. Chromium content in 100 g of fillet of pangasius covers around 60% of daily recommended intake. Chromium is an important element, which is involved in fat and carbohydrate metabolism, and its deficiencies are correlated with obesity (Anderson, 1998). In recent years many studies showed health promoting properties of chromium supplementation such as increased cell sensitivity to insulin and reduced risk of cardiovascular disease (Wilson et al., 1995; Wang et al., 2010).

Both pangasius and tilapia showed high levels of phosphorus, however the consumption of phosphorus in developed countries is usually above recommended intakes and its excess can impair calcium absorption and correlates with higher levels of parathormone in serum, which in turn can lead to disorders in calcium metabolism and osteoporosis (Kemi et al., 2009).

High amounts of sodium in pangasius fillets imported to both Poland and Ukraine, in contrast to low levels in pangasius fillets imported to Germany, suggests that PP and PU were additionally treated with sodium-containing food additives. High sodium content of both PP and PU is unfavorable, since high dietary consumption of sodium is correlated with hypertension, which in turn is recognized as the cause of approximately 7.6 million deaths per annum worldwide. Due to such a high death count associated with increased sodium intake a special Dietary Approaches to Stop Hypertension (DASH) have been developed. The DASH diet usually focuses on reduction of processed foods containing high amounts of sodium and one of the milestones of this diet is to reduce the consumption of red meat and increase the consumption of fish, especially the low-fat ones (Sacks et al., 2001; Arima et al., 2011). Meanwhile the average consumer might not be aware that consumption of 100 g of PP and PU provides 25% and 35% of RDI for sodium. Moreover, the fil-

lets which contained higher amounts of sodium came from self-service freezers and were unpacked, so there was no label which would inform the consumer about the sodium content of the fillet. Since frozen fillets from pangasius are usually much cheaper than other fish and seafood products available in Poland it can be assumed that they are mostly consumed by people from lower socio-economic status, which is the same group which frequently overuses salt and salted processed food products and can more directly be affected by sodium caused hypertension (Purdy et al., 2002; Darmon et al., 2008). Due to this we recommend enforcing more detailed labeling of fish fillets sold in Poland and Ukraine in self-service freezers. Such labeling should include more information regarding the content of sodium and fat in those fillets.

The addition of sodium chloride to meat and fish product increases its water holding capacity (WHC), and yield (Thorarinsdottir et al., 2001). Sodium chloride contains 38.85% of Na (Saxholt et al., 2008 b), so sodium from addition of NaCl into PP and PU accounts for 2231 mg/kg and 1932 mg/kg of fillet, respectively. The sodium chloride addition, although significantly higher, still does not explain all the differences between PP, PU and PG. Food additives from polyphosphates group were mentioned on the label of both PP and PU and available literature would suggest that such food additive could be sodium tripolyphosphate (STPP) (Sørensen, 2005). This would explain the higher amounts of sodium, if used in adequate quantities, but in such case PP and PU should have higher amounts of phosphorus, meanwhile it was PG which contained significantly higher amounts of phosphorus. It may be that additional sodium compounds are also added, probably to further increase WHC of treated fillets. One of such compounds could be sodium bicarbonate, which is successfully used to treat other fish fillets (Lopkulkiaert et al., 2009), although additional research would be needed to confirm this.

Conclusions

The study showed significant differences between Pangasius catfish groups in most analyzed quality parameters. Some of the differences could be explained by different handling and processing of pangasius fillets, like the lack of trimming in the case of PU, which increases the amount of fat and additional salt addition in the case of PP and PU which increased the sodium content. Although studied tilapias also differed significantly in some studied parameters those differences were not as pronounced as in pangasius fillets.

It was concluded that the quality parameters of frozen fillets from Pangasius catfish differ significantly depending on the type of processing performed before import. More detailed labeling of the fillets sold in self-service freezers should be provided for the final consumer since the nutritional value of the frozen pangasius fillets differed significantly.

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