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New trends in the seafood market. Sutchi catfish (*Pangasius hypophthalmus*) fillets from Vietnam: Nutritional quality and safety aspects

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Abstract

Sutchi catfish (*Pangasius hypophthalmus*) produced in the freshwater basins of Vietnam, available on the Italian market as frozen or thawed fillets, were studied for their nutritional quality and safety aspects. Proximate composition, mineral content, fatty acid profile, unsaponifiable components of the lipid fraction and drip loss during thawing at 5 °C were determined on the fillets. Fillets were characterised by high moisture levels (80–85%) and low protein (12.6–15.6%) and lipid (1.1–3.0%) contents. Total lipids were characterised by low cholesterol levels (21–39 mg/100 g), high percentages of saturated fatty acids (41.1–47.8% of total fatty acid) and low percentages of polyunsaturated fatty acids (12.5–18.8% of total fatty acids), which were mainly represented by linoleic acid (44–59% of total polyunsaturated fatty acids). The mineral composition was characterised by a high sodium content (222–594 mg/100 g), probably partially due to the sodium tripolyphosphate (E 451) used to retain moisture. As regards safety aspects, the quality of the samples analysed was good, with low residue levels of mercury, organochlorine pesticides and polychlorinated biphenyls.

Keywords: *Pangasius hypophthalmus*; Nutritional quality; Safety; Organochlorinated pollutants

1. Introduction

The sutchi catfish (*Pangasius hypophthalmus*), a freshwater fish present in the main water basins of South-East Asia, like the Mekong and Chao Phraya rivers, has been widely introduced into other Asiatic rivers and ponds for aquaculture. Freshwater farming in Vietnam, especially in the Mekong delta, has changed from a rural activity, providing local people with animal proteins, to an aquaculture enterprise. Raised in floating cages in rivers or ponds, sutchi catfish supply the Vietnamese domestic market and the export market which is in rapid expansion (Cacot & Lazard, 2004; Lazard & Cacot, 1997; Phillips, 2001). In 2006, the total production and export of *Pangasius* by Vietnam, far exceeded the values of 2005 (Josupeit, 2006).

As an omnivorous species, *Pangasius* is fed agricultural by-products, mainly rice bran, soy and fish by-products during rearing. Rearing techniques are under development, as well as the storage and processing technologies necessary for the product to be exported (Hung, Suhenda, Slembrouck, Lazard, & Moreau, 2004; Rahman, Islam, Halder, & Tanaka, 2006). Special efforts have been made to meet the quality and safety standards required for seafood products by importing countries, like the European Union, USA and Canada (Hung, Lazard, Mariojouls, & Moreau, 2003; Hung et al., 2004; National Agricultural Statistics Service (NASS) Agricultural Statistics Board, 2006). Russia and the European Union imported two thirds of the total sutchi catfish exported by Vietnam in 2006, while China, USA and Australia are currently reducing their imports (O'Sullivan, 2006).

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In Italy, Vietnamese suchi catfish is mostly marketed in fresh seafood markets and supermarkets as frozen or thawed fillets (120–260 g). Frozen fillets (generally individually quick-frozen) with glazing are sold individually or packed according to size into 1 kg packages. As stated on the pack labels, fillets are often treated with E 451 (sodium or potassium triphosphates), to retain water during processing. Non-phosphates (products with the same effect) are also used, in combination with salt; these substances can be declaration-free.

The quality and hygiene of *Pangasius* fillets, as of any seafood product, are dependent on the production chain: from the quality of the water where fish are raised, to the feed composition and safety, fish handling during filleting and freezing, transportation and storage up to the consumer's table.

Starting from these considerations, the objectives of this work were a study of the nutritional quality and an investigation into the presence of chemical contaminants like organochlorine pesticides, polychlorinated biphenyls (PCBs), and mercury in fillets of Vietnamese sutchi catfish (*P. hypophthalmus*) obtained from the Italian market, either frozen or thawed.

2. Materials and methods

2.1. Sampling

Vietnamese sutchi catfish (*P. hypophthalmus*) fillets of different size (170–260 g), boneless and skinless, were purchased, either frozen or thawed, in different Italian markets and supermarkets. Frozen fillets had 15–20% glazing declared on the label, together with the name of the trading company, lot number and expiry date of the product.

2.2. Chemical determinations

Fillets bought as defrosted products were analysed immediately. Fillets bought frozen were rapidly thawed under running cold water in a vacuum-sealed bag. The glaze liquid released in the bag during thawing was accurately discarded and drained fillets were homogenised in a Waring blender (Waring® Products Division, New Hartford, CT) for about 60 s at a low speed.

Moisture, crude protein and ash contents of the fish fillets were determined by AOAC (1990) methods. The pH was measured at 20 °C on a water:fish homogenate (2:1 w/w). Nonprotein nitrogen (NPN) was determined by the Kjeldahl method (AOAC 1990), after protein precipitation with 10% (w/v) trichloroacetic acid. Total lipids were extracted following the method of Bligh and Dyer (1959), slightly modified according to Kinsella, Shimp, Mai, and Weihrauch (1977). Sodium, potassium, calcium and magnesium were analysed in fish fillet homogenates by ion exchange liquid chromatography with suppressed conductivity, as already described (Orban et al., 2000). Mercury was analysed by instrumental activation analysis (Orban et al., 2000). Lyophilised samples were treated with nitric acid and hydrogen peroxide and ashed in a microwave digestion system (Milestone mls 1200 mega).

α-Tocopherol, squalene, and cholesterol were quantified by HPLC, after saponification of total lipids at 70 °C under nitrogen atmosphere (Orban et al., 2000). The HPLC system used was a Hewlett–Packard (Waldbronn, Germany) 1100 Series liquid chromatograph equipped with a UV/visible photodiode array detector. The analytical separations were performed using a stainless steel (25 cm × 4.6 mm i.d.) 5 μm Ultrasphere C18 column (Beckman, Palo Alto, CA).

Fatty acid profiles of the total lipids were determined after transesterification with a 1:1 (v/v) boron trifluoride in methanol (14%)/ methanol solution. Fatty acid methyl esters were extracted with hexane and quantified by gas chromatography using a 6890 Hewlett–Packard gas chromatograph with a flame ionisation detector, equipped with a SPB™ PUFA fused silica capillary column, (30 m × 0.25 mm i.d., 0.20 μm film thickness; Supelco Inc., Bellefonte, PA). Operating conditions were as previously described (Orban et al., 2000). Fatty acids were identified by comparison of retention times with authentic standards for percent area normalisation and by GC-MS (Varian 3900/Saturn 2100T GC-MS; Varian, Walnut Creek, CA) using a column with higher resolving power (Chrompack CP-Wax 52CB, 60 m × 0.32 mm i.d., 0.50 μm film thickness) and pure standards of each fatty acid. Confirmation criteria in the samples analysed were several: coincidence of standard and sample retention times, coincidence of standard and peak sample mass spectrum, coincidence between mass spectrum of peak sample and NIST (National Institute of Standards and Technology, Gaithersburg, USA) library. Relative quantities are expressed as wt% of total fatty acids.

2.3. Drip loss on thawing

The drip loss on thawing from fillets bought frozen and glazed was determined as described by Santos and Regenstein (1990), by placing frozen fillets in a glass funnel on the top of a flask. Fish and glassware, placed in a refrigerator, were tightly wrapped in a plastic bag to avoid tissue desiccation. Fillet thawing was allowed to occur overnight and percent thaw drip calculations were made after subtracting the weight of the glaze from that of the frozen fillet. The glaze weight was experimentally determined by the method of the Codex Alimentarius Commission (1995).

2.4. Organochlorinated pollutants

Fish fillets were homogenised with a Waring® blender for a few seconds at high speed and with an Ultra Turrax T25B (IKA, Staufen, Germany) for 1.5 min at 11,000 rpm.

Organochlorine pesticides and PCBs were extracted together with fat by means of acetone/petroleum ether (1/1 v/v). Sample purification and clean-up were accomplished by means of suitable phases, such as diatomaceous

earth, Florisil and C18, as described by Di Muccio et al. (1997).

Twenty-six organochlorine pesticides, for which action limits have been established by the Italian Health Ministry (Decree dated 19/5/2000), were searched for, together with eight more organochlorine pesticides not regulated by current Italian law but environmentally relevant. The maximum admissible levels set by Italian regulations vary with the total lipid content of the fish (Gazzetta Ufficiale della Repubblica Italiana, 2000).

Italian law has not yet established limits in seafood for polychlorinated biphenyls (PCBs). However, action limits have been established at a European level for seven congeners considered "pollution indicators": PCB 28, PCB 52, PCB 101, PCB 118, PCB 138, PCB 153, PCB 180 (Anonymous, 1992). Along with these indicators, 26 congeners chosen among those more widespread in the environment, have also been studied.

Instrumental analyses were performed with a Varian 3800 gas chromatograph equipped with a Saturn mass spectrometer 2000, an ECD, two injectors and two columns (30 m × 0.25 mm i.d., 0.25 μm film thickness) having different polarities. The first column (CP-Sil 24CB; Chrompack, Middelburg, The Netherlands) was connected to the ECD and the second (CP-Sil 8CB; Chrompack, Middelburg, The Netherlands) was connected to the mass spectrometer. Instrumental conditions were as previously described (Orban et al., 2004). Qualitative and quantitative analyses were carried out using a number of standard reference solutions. Each contaminant, with respect to the pure standard, had to meet a series of confirmation criteria for a positive identification: ECD retention time, MS retention time, mass spectrum. When necessary, MS/MS determinations were performed.

2.5. Analytical quality control

In the HPLC separation of unsaponifiables, linear calibration curves were obtained for α-tocopherol (27–140 μg/ml, $r^2 = 0.9999$), cholesterol (800–4800 μg/ml, $r^2 = 0.9999$) and squalene (30–80 mg/ml, $r^2 = 0.9999$). To compensate for any day-to-day variations, each day of analysis a set of standards was routinely saponified and run under the same conditions as the samples.

Repeatability of the HPLC method was estimated by calculating the CV of analytes concentration after repeated runs of a standard solution containing each compound at the level found in samples. The mean CV for pure α-tocopherol, cholesterol and squalene were 0.51%, 0.51% and 0.73%, respectively. The recovery of standard compounds after saponification was 96% for α-tocopherol, 98% for cholesterol, and 105% for squalene. After HPLC runs, the purity of analytes was checked by matching the UV/vis spectra of each peak with those of the standards.

The repeatability of the gas chromatographic response in the fatty acids analysis was evaluated both for samples and standards. Fish samples were prepared for the instrumental analysis and injected three times. The areas of peaks studied ($n = 25$) showed a CV of 0.4%, while the CV for retention times showed a mean value of 0.03%. All analytical standards ($n = 25$) were set at four different concentrations in triplicate. An appropriate internal standard (15:1 $n-5$) was used. Subsequently 300 injections from the 300 prepared vials were performed and in this way 25 calibration curves were obtained. The mean correlation coefficient observed (r^2) was 0.9877, 0.9606 and 0.9991 being the minimum and maximum values, respectively. As regards recoveries, a standard oil with known amounts of selected fatty acids (C14:0 = 33%, C16:0 = 33% and C18:1 $n-9$ = 33%) was analysed in triplicate. Results were as follows: C14:0 = 29.9%, C16:0 = 34% and C18:1 $n-9$ = 36.1%.

Finally, in order to test the robustness of the method of fatty acid determination, two different derivatisation procedures were applied on the same sample (the first one was the derivatisation step routinely used in our laboratory). The mean CV observed for the two sets of results was 4.2%.

As regards organochlorinated pollutants, in order to asses the accuracy of the method, a known matrix-sample was spiked with eight standard contaminants and analysed together with the catfish samples.

The recovery rates were as follows: γ-HCH = 102%, Heptachlor endo-epoxide = 97%, Heptachlor = 88%, 4,4′-DDE = 83%, Aldrin = 79%, PCB 28 = 81%, PCB 52 = 76%, PCB 101 = 71%.

These eight values are identical to those that we obtained in an International Ring Test (Fapas®, 2003), when recoveries were at a good level for all the 67 contaminants studied.

2.6. Statistical analysis

Results are reported as the average ± standard deviation and range of values detected in eight samplings from different seafood markets and supermarket chains. For each sampling eight fillets selected at random were analysed. Two pools of four fillets were prepared and homogenised separately. Each homogenate was analysed twice.

3. Results and discussion

The sutchi catfish has white or pale pink flesh. Unlike cod fillets, for which they are often substituted because of their white flesh, *Pangasius* fillets are characterised by absence of fishy odour, small bones and skin. When cooked, their flavour is delicate and their texture firm, allowing a wide range of culinary preparations.

The chemical–nutritional composition of *P. hypophthalmus* fillets from fish reared in Vietnam and available on the Italian market as frozen or defrosted products was characterised by high moisture (80–85 g/100 g) and relatively low protein (12.6–15.6 g/100 g) and lipid (1.1–3.0 g/100 g) contents (Table 1). Within the ranges reported, the lower levels of moisture and the higher levels of nutrients were found in fillets purchased as "thawed product", indicating that

Table 1
Proximate composition of *Pangasius hypophthalmus* fillets (170–260 g) from Vietnam sold in Italy

	Mean ± SD	Minimum	Maximum
pH	7.73 ± 0.17	7.56	7.96
Moisture (g 100 g^{-1} wet fillet)	83.57 ± 2.30	80.14	85.02
Protein (g 100 g^{-1} wet fillet)	13.60 ± 1.34	12.65	15.59
Total lipid (g 100 g^{-1} wet fillet)	1.84 ± 0.92	1.11	3.04
Nonprotein N (g 100 g^{-1} wet fillet)	0.16 ± 0.02	0.14	0.18
Ash (g 100 g^{-1} wet fillet)	1.25 ± 0.19	1.03	1.50

Table 2
Unsaponifiable lipid components of *Pangasius hypophthalmus* fillets from Vietnam sold in Italy

	Mean ± SD	Minimum	Maximum
Cholesterol (mg 100 g^{-1} wet fillet)	29.30 ± 7.65	21.25	38.88
α-Tocopherol (mg 100 g^{-1} wet fillet)	0.22 ± 0.23	0.04	0.56
Squalene (mg 100 g^{-1} wet fillet)	0.41 ± 0.29	0.15	0.80
Cholesterol (mg g^{-1} lipid)	17.39 ± 4.24	12.79	22.40
α-Tocopherol (mg g^{-1} lipid)	0.11 ± 0.07	0.02	0.18
Squalene (mg g^{-1} lipid)	0.20 ± 0.05	0.13	0.26

moisture loss during thawing and shelf life have an impact not only on the sensory properties of fillets but also on their nutritional profile. *P. hypophthalmus* fillets were also characterised by a low cholesterol content (21–39 mg/100 g, Table 2). From a nutritional point of view, the presence of low cholesterol levels is a favourable attribute, considering the current dietary recommendation to reduce the daily intake of cholesterol in the human diet (WHO, 1990).

The fatty acid profile of total lipids extracted from sutchi catfish fillets was dominated by saturated fatty acids (41.1–47.8% of total fatty acids), mainly represented by palmitic (C16:0, 27.5–28.8% of total fatty acids) and stearic acids (C18:0, 8.9–15.4% of total fatty acids) (Table 3). Similar percentages are reported by Men, Thanh, Hirata, and Yamasaki (2005) for *P. hypophthalmus* cultivated in the Mekong river delta of Vietnam. Monounsaturated fatty acids, amounting altogether to 33–37% of total fatty acids, were mostly represented by oleic acid (C18:1, *n*−9) which accounted for about 90% of total monounsaturates (28.9–33.8% of total fatty acids). Total polyunsaturated fatty acids (PUFA) were present at very low percentages (12.5–18.8% of total fatty acids) in sutchi catfish fillets, while fish is commonly regarded as a precious source of PUFA in the human diet. The polyunsaturated lipid fraction of *P. hypophthalmus* fillets was characterised by a high proportion of *n*−6 PUFA and by low *n*−3/*n*−6 ratio values, a characteristic common to many freshwater fish species (Henderson & Tocher, 1987).

The prevalent PUFAs in sutchi catfish fillets were linoleic acid (C18:2 *n*−6, 7–8% of total fatty acids), which alone accounted for 44–59% of total PUFA, arachidonic acid (C20:4 *n*−6, 1.5–3.6% of total fatty acids) and docosahexaenoic acid (C22:6 *n*−3, 1.7–3.6% of total fatty acids).

Table 3
Fatty acid profiles of total lipids in *Pangasius hypophthalmus* fillets from Vietnam sold in Italy (% of total fatty acids)

	Mean ± SD	Minimum	Maximum
C12:0	0.11 ± 0.03	0.07	0.13
C13:0	0.00 ± 0.00	0.00	0.00
C14:0	4.77 ± 0.91	3.86	5.56
C15:0	0.18 ± 0.04	0.13	0.22
C16:0	28.19 ± 0.56	27.49	28.84
C17:0	0.17 ± 0.04	0.11	0.22
C18:0	11.17 ± 2.88	8.92	15.38
C20:0	0.15 ± 0.01	0.14	0.17
C21:0	0.03 ± 0.00	0.03	0.03
Total saturated	44.77 ± 2.77	41.17	47.83
C14:1 *n*−5	0.03 ± 0.01	0.03	0.04
C161 *n*−7	1.64 ± 0.27	1.34	1.98
C18:1 *n*−9	31.01 ± 2.08	28.89	33.78
C18:1 *n*−7	0.92 ± 0.32	0.60	1.26
C20:1 *n*−9	1.05 ± 0.05	0.98	1.09
C22:1 *n*−9	0.03 ± 0.00	0.02	0.03
Total monounsaturated	34.68 ± 1.73	33.28	36.97
C18:2 *n*−6	7.87 ± 0.49	7.16	8.19
C18:3 *n*−6	0.26 ± 0.09	0.18	0.36
C18:3 *n*−3	0.44 ± 0.12	0.28	0.57
C18:4 *n*−3	0.07 ± 0.03	0.04	0.10
C20:2 *n*−6	0.50 ± 0.08	0.42	0.59
C20:4 *n*−6	2.11 ± 1.00	1.55	3.61
C20:5 *n*−3	0.58 ± 0.51	0.19	1.31
C22:4 *n*−3	0.37 ± 0.18	0.24	0.64
C22:5 *n*−3	0.67 ± 0.36	0.34	1.06
C22:6 *n*−3	2.67 ± 1.01	1.70	3.64
Total polyunsaturated	15.55 ± 2.92	12.48	18.76
Total *n*−3 fatty acids	4.43 ± 1.93	2.58	6.69
Total *n*−6 fatty acids	11.11 ± 1.55	9.89	13.38
Ratio *n*−3/*n*−6	0.40 ± 0.17	0.26	0.64

Fatty acids belonging to the *n*−3 series were present at very low levels (sum of *n*−3 PUFA: 2.6–6.7% of total fatty acids), docosahexaenoic acid accounting alone for more than 60% of total *n*−3 PUFA. The low lipid content of *P. hypophthalmus* muscle and the prevalence of *n*−6 over *n*−3 is an attribute of nutritional relevance to human nutrition, considering that seafood is potentially the only significant dietary source of *n*−3 PUFA in the human diet.

The lipid profile of sutchi catfish muscle, apart from an undeniable species-specific genetic factor, may also result from the diet administered to fish during rearing, which is mostly of vegetable origin. It is well known, that the diet composition, in particular its lipid profile, has a quantitative and qualitative influence on the fatty acid composition of fish lipids (Henderson & Tocher, 1987; Steffens, 1997). In addition, it is also possible that nutrient loss or modification occurring during fish processing and storage (freezing, frozen storage and thawing) may affect the nutritional value of the final product.

Drip-loss analyses on frozen fillets gave results ranging from 6.0% to 8.8%. The lower values were registered by samples that had E451 (triphosphate salt) added during processing, as declared on the pack labels. This additive, permitted by current regulations, improves water retention

by proteins during processing and helps the maintenance of moisture and quality of fillets, in particular by reducing the amount of thaw drip.

As regards minerals, sutchi catfish fillets have shown a variable but high sodium content, probably due to the polyphosphates added (Table 4). On the contrary, magnesium levels were found to be lower than in other fish species studied (Orban et al., 2006; Orban et al., 2007).

Table 4
Minerals in *Pangasius hypophthalmus* fillets from Vietnam sold in Italy

	Mean ± SD	Minimum	Maximum
Na (mg 100 g^{-1} wet fillet)	387.5 ± 135.9	222.6	594.0
K (mg 100 g^{-1} wet fillet)	335.6 ± 3.42	330.7	340.2
Mg (mg 100 g^{-1} wet fillet)	12.08 ± 0.15	11.9	12.3
Ca (mg 100 g^{-1} wet fillet)	8.03 ± 1.50	5.50	10.10
Hg (μg 100 g^{-1} wet fillet)	0.03 ± 0.01	0.03	0.04

Table 5
Organochlorine pesticides residues in *Pangasius hypophthalmus* fillets from Vietnam sold in Italy (μg kg^{-1} wet fillet)[a]

	Sample 1	Sample 2		Sample 1	Sample 2
Aldrin	n.d.	n.d.	Endrin[e]	n.d.	n.d.
Dieldrin	n.d.	n.d.			
Sum[b]	**n.d.**	**n.d.**	α-HCH	n.d.	n.d.
			β-HCH	n.d.	n.d.
4,4′-DDT	n.d.	0.27	δ-HCH	n.d.	n.d.
4,4′-DDD	0.07	0.31	**Sum**[f]	**n.d.**	**n.d.**
4,4′-DDE	0.05	2.03			
2,2′-DDE	**n.d.**	**n.d.**	γ-HCH (Lindane)[g]	n.d.	n.d.
4,4′-DDM	n.d.	n.d.	HCB[f]	0.01	0.01
4,4′-DDMU	0.01	n.d.			
2,4′-DDT	n.d.	n.d.	Heptachlor	n.d.	n.d.
2,4′-DDD	n.d.	n.d.	Heptachlor endo-epoxide	n.d.	n.d.
2,4′-DDD olefin	n.d.	n.d.	Heptachlor exo-epoxide	n.d.	n.d.
2,4′-DDE	n.d.	n.d.	**Sum**[d]	**n.d.**	**n.d.**
Sum[c]	**0.13**	**2.61**			
α-Chlordane	n.d.	n.d.	Octachlorostyrene	n.d.	n.d.
γ-Chlordane	n.d.	n.d.	α-Endosulfan	n.d.	n.d.
Oxychlordane	n.d.	n.d.	α-Chlordene	n.d.	n.d.
cis-Nonachlor	n.d.	0.02	γ-Chlordene	n.d.	n.d.
trans-Nonachlor	n.d.	0.04	Mirex	n.d.	n.d.
Sum[d]	**n.d.**	**0.06**	Quintozen	n.d.	n.d.
			Methyl-chlorpyriphos	n.d.	n.d.
			Chlorpyriphos	0.17	n.d.

n.d. = not detected.
[a] When not specified, action limit is not established.
[b] Action limit established by the Italian Government (=5 μg kg^{-1}) and by OSPAR countries (=100 μg kg^{-1}).
[c] Action limit established by the Italian Government (=50 μg kg^{-1}) and by OSPAR countries (DDT + DDE + DDD = 500 μg kg^{-1}).
[d] Action limit established by the Italian Government (=5 μg kg^{-1}).
[e] Action limit established by the Italian Government (=1 μg kg^{-1}).
[f] Action limit established by the Italian Government (=10 μg kg^{-1}) and by OSPAR countries (HCB = 50 μg kg^{-1}; α-HCH + β-HCH = 50 μg kg^{-1}).
[g] Action limit established by the Italian Government (=25 μg kg^{-1}) and by OSPAR countries (=100 μg kg^{-1}).

Fish is easily subject to chemical contamination, especially the species living in freshwater environments characterised by high anthropic pollution. Among the chemical contaminants examined, mercury was present but at extremely low levels in the samples examined (Table 4).

The presence of organochlorine pesticides and PCBs in the aquatic environment represents one of the most debated environmental questions, due to their ubiquitous presence, accumulation in the food chain and influence on the public health (Smith & Gangolli, 2002). In living organisms, due to their lipophilic nature, these substances accumulate in the lipids. From our study, the levels of organochlorine pesticides and PCBs detected in sutchi catfish fillets from Vietnam were very low (Tables 5 and 6). Similar results have been obtained by other authors in a study on *Pangasius* catfish reared in Vietnam (Minh et al., 2006). However, considering that, despite the ban in Western countries, organochlorine pesticides and PCBs

Table 6
Polychlorinated biphenyl residues in *Pangasius hypophthalmus* fillets from Vietnam sold in Italy (μg kg^{-1} wet fillet)[a]

	Sample 1	Sample 2
PCB 151	n.d.	n.d.
PCB 74	n.d.	n.d.
PCB 49	n.d.	n.d.
PCB 206	0.02	n.d.
PCB 119	n.d.	n.d.
PCB 136	n.d.	n.d.
PCB 47	0.01	n.d.
PCB 97	n.d.	n.d.
PCB 188	n.d.	n.d.
PCB 185	n.d.	n.d.
PCB 155	n.d.	n.d.
PCB 198	n.d.	n.d.
PCB 194	n.d.	n.d.
PCB 183	n.d.	n.d.
PCB 87	n.d.	n.d.
PCB 110	n.d.	n.d.
PCB 104	n.d.	n.d.
PCB 28[b]	n.d.	0.02
PCB 52[c]	n.d.	n.d.
PCB 101[b]	n.d.	n.d.
PCB 118[b]	n.d.	0.07
PCB 138[d]	n.d.	0.09
PCB 153[d]	n.d.	0.26
PCB 180[b]	n.d.	0.31
PCB 44	n.d.	n.d.
PCB 132	n.d.	n.d.
PCB 70	n.d.	n.d.
PCB 128	n.d.	n.d.
PCB 31	n.d.	<0.01
PCB 187	n.d.	0.07
PCB 170	n.d.	n.d.
PCB 5	n.d.	n.d.
PCB 66	n.d.	n.d.
Sum	0.03	0.82

n.d. = not detected.
[a] When not specified, action limit is not established.
[b] Action limit established by OSPAR countries (=80 μg kg^{-1}).
[c] Action limit established by OSPAR countries (=40 μg kg^{-1}).
[d] Action limit established by OSPAR countries (=100 μg kg^{-1}).

were intensively used until recently in Vietnam and considering also the high estimated dietary intake of persistent organochlorine compounds by Vietnamese people and the serious concern on the health of the local population (Kannan, Tanabe, Quynh, Hue, & Tatsukawa, 1992; Minh et al., 2004), a careful monitoring of residue levels in the aquatic food chain is desirable.

4. Conclusions

The absence of fishy odour, spines, small bones and skin, the delicate flavour and the firm texture when cooked, allow a wide range of culinary preparations with *Pangasius* fillets. These characteristics, together with their availability on the market in standard size, make sutchi catfish fillets particularly suitable to the demands of the food service industry and restaurants.

The nutritional quality of the Vietnamese *P. hypophthalmus* fillets analysed in this study may not be considered high. In fact, besides having low cholesterol levels, a favourable characteristic for human nutrition, sutchi catfish fillets were characterised by a fatty acid profile unusual for most fish species and devoid of those nutritional characteristics that induce dieticians and nutritionists to recommend the consumption of fish and seafood products at least twice a week. PUFA, in particular those of the $n-3$ series, are a class of nutrients fundamental in the human diet for their platelet anti-aggregating and blood pressure-reducing properties and for their role in the prevention of cardiovascular diseases. The high proportion of saturated fatty acids, oleic and linoleic acid and the low $n-3/n-6$ PUFA ratio levels differentiate *Pangasius* from most of the other fish species.

E 451 and other polyphosphates present little hazard to health. Nevertheless, it is possible for essential food components to be harmful if taken in excess and international scientific authorities have recommended that the daily consumption of phosphorus should not exceed a certain level (National Research Council, 1989).

As regards safety aspects, the quality of samples analysed was good, at least with regard to residual levels of mercury, organochlorine pesticides and polychlorinated biphenyls. However attention should be paid to the area of provenance of fish and to the quality of the aquatic environment, since the contamination level of the fish is clearly connected to these factors.

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