DIOXINS AND PCBs IN FARMED AND WILD FISH. HOW IMPORTANT IS THE DIFFERENCE?

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Introduction

The health benefits of fish consumption are generally acknowledged, in particular in relation to the protection against coronary heart disease offered by the omega-3 fatty acids.[1] However, fish and fisheries products are also known to be a significant source of dietary exposure to a number of environmental contaminants including dioxins and PCBs.[2-5] A paper published in Science magazine in early 2004 prompted a wide public debate in the US and in Europe about differences in the levels of environmental contaminants in wild and farmed salmon and the associated risks to health.[6] Since June of the previous year, a working group comprising members of the UK Scientific Advisory Committee on Nutrition (SACN) and the Committee on the Toxicity of Chemicals in Food, Environment and Consumer Products (COT) had already been reviewing existing evidence of the benefits and risks of eating fish with a view to producing comprehensive advice for consumers. In July 2003 the UK started to collect samples for an extensive survey for dioxins and PCBs in farmed and wild fish and shellfish. The primary objective of the survey was to allow a robust dietary intake of dioxins and PCBs from fish to be estimated, but the design also provided the opportunity for a statistical comparison of levels in farmed and wild salmon as well as an assessment of the variability in levels within individual samples of a number of farmed and wild species. This survey updated and expanded on two earlier surveys carried out by the Ministry of Agriculture, Fisheries and Food.[7-8] It also provided data to inform the review of farmed and wild fish carried out by the European Food Safety Agency.[9]

Table 1: Species and types tested

Fresh wild fish	Cod, Coley, Dogfish, Eel, Haddock, Hake, Halibut, Herring, Lemon Sole, Mackerel, Plaice, Red snapper, Salmon (Alaskan), Salmon (Atlantic), Sardine/Pilchard, Sea Bass, Shark, Sprat, Swordfish, Tuna, Turbot (Greenland), Turbot (UK), Whitebait, Whiting
Farmed fish	Halibut, Salmon (Atlantic), Rainbow trout, Sea bass, Sea bream, Sea trout, Turbot (UK)
Organic fish	Rainbow trout, Salmon (Atlantic)
Shellfish	Crab, Mussels, Oysters, Prawns (cold water), Prawns (warm water), Scallops, Scampi
Canned	Anchovy, Crab, Herring (rollmop), Mackerel, Pilchard, Salmon (Alaskan), Sardine, Tuna
Highly processed	Fish paste, Surimi

Materials and methods

The sampling plan, covering most of the fish and shellfish available on the UK market, was produced by the University of Bristol. A total of 24 species of fresh wild fish, seven of farmed fish, seven of fresh shellfish, eight of canned fish and shellfish and two highly processed fish products were included (a more comprehensive survey of processed products has subsequently been carried out). Samples were purchased from retail outlets and specialist suppliers throughout the UK. Up to 60 individual samples per species and category (wild, farmed, canned and/or otherwise processed), i.e. a total of over 2,800 samples, were obtained in order to ensure that the survey was representative of overall consumer exposure. Samples of larger species were generally purchased as steaks or fillets. In order to take account of seasonal variations, samples were purchased regularly over a period of up to 12 months, except for fresh herring, mackerel and sprats which have a limited season.

For each species and category, the edible portions of the samples were homogenised individually and portions of each homogenate were then combined and further homogenised into a single composite sample. Final homogenates comprised 60 samples per species and presentation, with the exception of fresh herring, mackerel, farmed and wild Atlantic salmon and farmed rainbow trout, for which composites were made from 30 samples with a further 30 being tested individually (28 for trout). The large numbers of samples were required to ensure that the average concentrations required for estimating dietary intakes would be statistically robust. A small number of organic salmon (4) and organic trout (6) were analysed as individual samples.

Table 2: Results for individual samples

	No. of samples	Concentration ranges, ng WHO-TEQ/kg fresh weight (mean, standard deviation in brackets)		
		Dioxins	PCBs	Total
Herring (fresh)	30	0.7-2.7 (1.5, 0.6)	0.6-6.9 (1.9, 1.2)	1.3-9.5 (3.3, 1.7)
Atlantic salmon (farmed)	30	0.3-0.9 (0.6, 0.2)	1.0-2.6 (1.8, 0.5)	1.3-3.4 (2.4, 0.7)
Organic salmon	4	0.4-0.7 (0.6, 0.2)	1.1-2.0 (1.7, 0.5)	1.5-2.7 (2.3, 0.6)
Mackerel (fresh)	29*	0.1-1.4 (0.5, 0.3)	0.4-4.2 (1.3, 1.0)	0.5-5.6 (1.7, 1.3)
Atlantic salmon (wild)	30	0.03-1.1 (0.5, 0.3)	0.07-2.8 (0.9, 0.5)	0.1-3.6 (1.4, 0.8)
Trout (farmed)	28	0.2-0.4 (0.3, 0.08)	0.4-1.2 (0.8, 0.2)	0.6-1.6 (1.1, 0.2)
Organic trout	6	0.2-0.3 (0.3, 0.05)	0.5-0.8 (0.7, 0.07)	0.7-1.1 (0.9, 0.1)

* One sample containing dioxin 6.9 ng/kg and PCB 21.0 ng/kg excluded from statistics

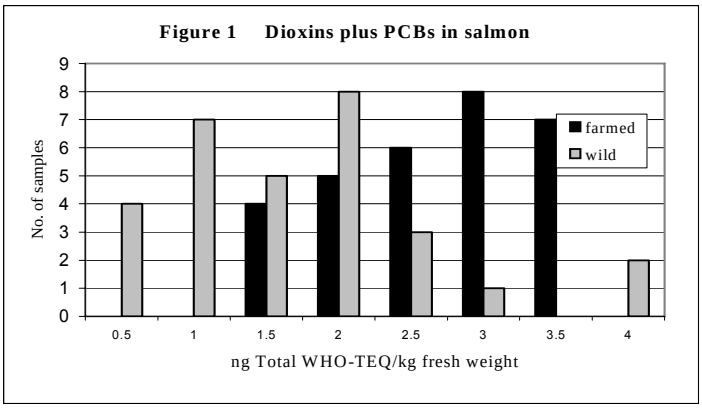
Composite and individual samples were extracted and analysed for the 17 dioxins and furan congeners and 12 dioxin-like PCBs assigned toxic equivalency factors by the World Health Organisation by the Central Science Laboratory (CSL) using high resolution gas chromatography coupled with high or low resolution mass spectrometry following methodology described elsewhere.[10] Other PCB congeners that are thought to show other toxic effects or are indicators of environmental pollution were also analysed but are not reported here. The composite samples were also analysed for brominated dioxins and BFRs which are also not reported in this paper.

Results and Discussion

The full results of the survey are not presented here. Total TEQ levels for dioxins plus PCBs in white fish and shellfish (with the exception of whole crab) were all <1.0 ng/kg whole weight. Instead, we focus on the fatty and oily fish and those for which data for both farmed and wild are available.

Table 2 lists the results and statistics for the samples tested individually. A statistical analysis of the data for Atlantic salmon indicates that, whilst there was no significant difference between the dioxin levels in wild (0.03-1.1 ng WHO-TEQ/kg, mean 0.5) or farmed (0.3-0.9, mean 0.6) salmon, the PCB levels were higher in farmed (1.0-2.6, mean 1.8) than wild (0.07-2.8, mean 0.9, $p<0.001$). The ratio of PCBs to dioxins of 2.8 in the farmed fish c.f. 2.0 for wild is very close to the ratio of PCBs to dioxins in fish feed.[11] With regard to the total TEQ, the difference between farmed and wild is 1.0 ng/kg with a 95% confidence interval of 0.7-1.3, indicating that this difference is statistically significant. The total TEQ data are presented graphically in Figure 1.

Figure 1 Dioxins plus PCBs in salmon



The concentrations of dioxins plus dioxin-like PCBs in the organic salmon and trout samples, which are of course farmed, were similar to those found in conventionally farmed fish, although there were insufficient organic samples to make a valid statistical comparison.

Table 3 shows the results for composite samples. In the case of those species also tested individually, the results were in generally good agreement with the means for the individual samples. The first point to note from the table is that the fish found to contain the highest levels of dioxins and PCBs - sprats, pilchards, sardines, herring and whitebait, are all wild species. Wild sea bass, which is not generally regarded as an oily fish (being relatively low in omega-3 oils[12]) was also among those species containing higher levels of dioxins and PCBs. In contrast, farmed sea bass contained relatively low levels. Although based on single analyses, in both cases the samples tested were composites made up of 60 individual retail samples. A similar trend was seen for wild and farmed UK turbot, although the difference was less marked. In contrast, the dioxin and PCB levels in farmed halibut were approximately twice those of wild halibut.

Table 3: Results for composite samples

	Concentrations (ng WHO-TEQ/kg fresh weight)		
	Dioxins	**PCBs**	**Total**
Sardines/pilchards	1.1	4.9	6
Sprat	1.8	2.5	4.3
Sea bass (wild)	0.7	3.0	3.7
Herring *	1.5	2.2	3.6
Whitebait	1.1	2.1	3.1
Atlantic salmon (farmed)*	0.7	1.9	2.6
Halibut (farmed)	0.7	1.7	2.4
Turbot (Greenland, wild)	0.8	1.6	2.3
Sardines (canned)	0.1	2.2	2.3
Dogfish	0.6	1.6	2.2
Mackerel*	0.4	1.5	1.9
Herring (rollmop)	0.8	0.9	1.7
Atlantic salmon (wild)*	0.5	1.1	1.6
Turbot (UK, wild)	0.4	1.2	1.5
Sea bass (farmed)	0.3	1.2	1.5
Sea bream (farmed)	0.3	1.2	1.5
Sea trout (farmed)	0.4	1.0	1.4
Eel	0.4	0.9	1.3
Halibut (wild)	0.3	0.8	1.1
Rainbow trout (farmed)*	0.3	0.7	1.0
Turbot (UK, farmed)	0.2	0.8	1.0

* Composite of 30 samples, remainder 60.

Estimated intakes are shown in Table 4. These are based on an average portion size of 140g or 70g, for a normal adult consuming either one or two portions of fish per week on top of the normal diet (excluding fish). Estimated exposure from the rest of the diet is taken from the most recent Total Diet Study for dioxins and PCBs in the UK.[13] Although farmed salmon and halibut appear above their wild counterparts, the figures in Table 4 again illustrate that exposure through the consumption of some wild fish species may be higher still. Taken with figure 1, which shows the considerable overlap in the distribution of results, it seems that drawing a distinction between farmed and wild fish in terms of exposure to dioxins and PCBs thus becomes somewhat irrelevant. Furthermore, there are opportunities to control and reduce the level of contaminants in farmed fish through increasingly tight regulations on feed.

Based on the outcome of this survey, the UK Food Standards Agency reiterated its existing advice, which is that girls and females of child bearing age should consume no more than two portions per week of oily fish, whilst males and females past child bearing age may consume up to four portions, and suggested that consumers should consider eating a variety of fish species.[14] Halibut and turbot, like sea bass, are not normally considered as oily fish for the purposes of giving nutritional advice, because they contain relatively low levels of omega-3 fatty acids. However, the dioxin and PCB levels found led the Agency to refine its advice on fish consumption to recommend limited consumption of these species along with dogfish, sea bream and crab.

In formulating its advice, the Agency has not made any distinction between wild and farmed fish, although as a general policy it recognises that consumers may have concerns about the sustainability of fishing practices and fish supplies and encourages them to seek further information on this issue from the Marine Stewardship Council or a similar body.

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Table 4 Estimated intakes for a 60 kg adult

Species	Portion size (g)	Average daily intake, pg WHO-TEQ/kg bw	
		1 weekly portion	2 weekly portions
Sprat	140	2.1	3.5
Sea bass (wild)	140	1.9	3.1
Herring	140	1.9	3.1
Sardines/pilchards	70	1.7	2.6
Atlantic salmon (farmed)	140	1.5	2.4
Halibut (farmed)	140	1.5	2.3
Turbot (Greenland)	140	1.4	2.2
Dogfish	140	1.4	2.1
Mackerel	140	1.3	1.9
Atlantic salmon (wild)	140	1.2	1.7
Whitebait	70	1.2	1.7
Turbot (UK, wild)	140	1.2	1.7
Sea bream	140	1.2	1.6
Sea bass (farmed)	140	1.1	1.6
Sea trout (farmed)	140	1.1	1.6
Eel	70	1.1	1.5
Sardines (canned)	70	1.0	1.4
Wild Halibut	140	1.0	1.4
Turbot (UK, farmed)	140	1.0	1.3
Rainbow trout (farmed)	140	1.0	1.3
Herring (rollmop)	70	0.9	1.2