Bull. Environ. Contam. Toxicol. (1988) 41:670–677

Environmental Contamination and Toxicology

Distribution Pattern and Reduction of Polychlorinated Biphenyls (PCB) in Bluefish *Pomatomus saltatrix* (Linnaeus) Fillets through Adipose Tissue Removal

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Bluefish, (Pomatomus saltatrix), a migratory pelagic species of fish usually travel in large groups of like size along the Atlantic coast. Bluefish of all sizes are caught both commercially and recreationally for human consumption. Biologically, bluefish is a fast growing, fatty fish with a moderately long lifespan. Blues average 3 Lbs (1.4 Kg) at age 3 , 7 Lbs (3.2 Kg) at age 5, 15 Lbs (6.8 Kg) at age 10, and 19 Lbs (8.6 Kg) at age 14 (Wilk 1977; Sargent and Boreman 1984). Owing to its predaceous nature, bluefish feed throughout the water column on a large variety of smaller fish and invertebrates. Bluefish bioaccumulate contaminants such as polychlorinated biphenyls (PCB) into various adipose tissues from the water column and through the marine food chain (Sargent and Boreman 1984).

Two recent reports (National Marine Fisheries Service, Food and Drug Administration and Environmental Protection Agency 1986; 1987) concluded that PCB concentrations for all except some of the large bluefish caught along the Atlantic coast fell below the limit of 2 ug/g set by FDA. That report also stated that eating bluefish poses no health threat to ordinary consumers, because they consume a variety of fish from various locations, most of which contain little or no measurable PCB. Additionally, the report stated, that 15.6 % of the large bluefish contain PCB concentrations that exceed the FDA limit of 2 ug/g. There may be reason for states to control the consumption of large bluefish to recreational and subsistence fishermen who repeatedly fish in the same waters and consistently eat their catch.

The purpose of this study was to observe the distribution pattern of PCB in the various edible tissues. Further, it was to determine if the removal of

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adipose tissues would result in reduced PCB level and therefore decrease PCB exposure to the consumer.

MATERIALS AND METHODS

Bluefish of a particular size (650 - 850 mm total length) were purchased from commercial fishermen along the North Carolina coast in March of 1987. Specimens were packed in dry ice and transported to the laboratory in cardboard containers and frozen at -30°C.

Two experiments were conducted. In experiment # 1, One fillet from each of seven specimens was divided into two regions along the center, and was further divided into six vertical zones making a total of 12 portions (Figure 1). The skin was removed from each portion. Those portions larger than 50.0 grams were individually homogenized, and 50.0 grams taken for analysis. For portions less than 50.0 grams the entire portion was used for analysis.

In experiment # 2, One fillet from each of 21 specimens was prepared using a modified method of Skea et al. (1979). Briefly, this method involved making a shallow cut through the skin from the base of the head to the tail along the dorsal fin; and along the belly from the base of the pectoral fin. Another cut was made behind the gills. The skin was grasped with a pair of pliers and pulled towards the tail and discarded. After the skin was removed, the remaining bellyflap including the rib cage and an 1/2 in (13 mm) of flesh along the dorsal fin were also discarded (see shaded areas in Figure 1). Finally, the remaining flesh was homogenized and labelled "trimmed". The entire fillet from the other side of the specimen was homogenized and labelled "untrimmed". During sample processing, the left and right fillets were alternately distributed between the trimmed and untrimmed samples.

Analytical procedures were in accordance with the FDA's Pesticides Analytical Manual, Vol. I (PAM), (Food and Drug Administration 1978). Briefly stated, sample portions were extracted with petroleum ether. The resultant extract was cleaned-up by partitioning with acetonitrile. The clean-up was continued by partitioning the extract in acetonitrile with petroleum ether and water. The clean-up ended with Florisil column chromatography of the petroleum ether solution. Two eluates were used for Florisil column separations: first, 250 mL of petroleum ether and second, 200 of 6 % ethyl ether in petroleum ether. The PCB were eluted in the petroleum eluate and the pesticides in both eluates. PCB and pesticide residues were quantitated on

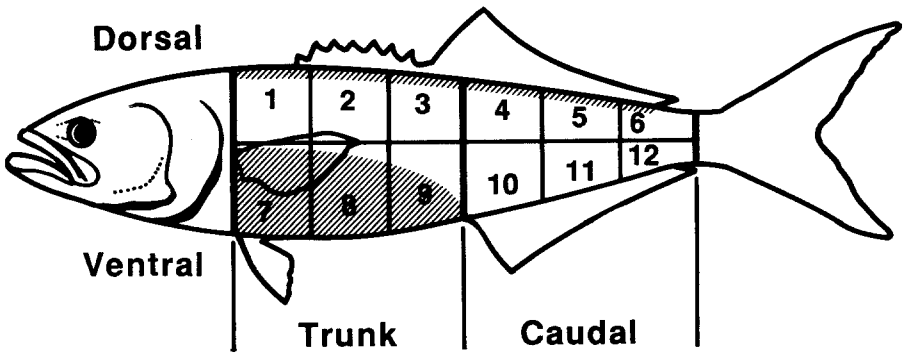

Figure 1. Muscle tissue sampling zones. The shaded areas were discarded.

a Perkin Elmer Model Sigma 2000 equipped with ^{63}Ni detectors, automatic sampler injection, and chromatographic intelligent terminal. For PCB determination, a mixed standard containing 3 parts Aroclor 1254 and 2 parts Aroclor 1260, which most resembled the sample chromatogram, was used for quantitation. For pesticide determinations, relative retention times of peaks in the sample were matched against peaks in the standards and the concentrations were calculated from matching peak areas. Confirmation of peaks was determined on a high resolution capillary column. For PCB determinations, total peak area was used for quantification. All PCB and pesticides data were validated by quality control and assurance procedures which included determinations of spiked samples, benchmark samples, and procedural blanks.

Statistical tests were performed using a PC-SAS computing system. Pearson's correlation coefficient was used to determine closeness of linear relationships. One way analysis of variance and means grouped by Duncan's test were used to determine significant differences (SAS Institute Inc. 1986). Also, pooled t-test was used to compare means. Since PCB concentrations varied greatly among specimens, the PCB data (Experiment # 1) was normalized by using PCB ratios (% PCB per zone / % fillet per zone).

RESULTS AND DISCUSSION

In large bluefish, differences in PCB ratios (% PCB per zone / % fillets per zone) were found in various

zones of the body (Table 1). A definite dorsal to ventral gradation in PCB ratio was observed among the zones ($P < 0.05$). In particular, within the trunk area, the ventral section which includes the rib cage and the bellyflap (zones 7,8,9) had significantly higher PCB ratios ($P < 0.05$) than the corresponding zones (zones 1,2,3) in the dorsal section. The highest PCB ratios were found in zone 7 and 8, the front and center portions of the ventral trunk, and followed by zone 9. There were no significant differences in PCB ratios among the corresponding zones in the ventral and dorsal section within the caudal area ($P > 0.05$). Further, there was a general decrease of PCB ratios in the various zones of the body from the anterior to the posterior. The lowest PCB ratios were found in the posteriormost zones (zones 5,6,11 and 12).

Table 1. Distribution patterns of PCB (ug/g, wet weight) and lipid (%, wet weight) in various zones of the body of large bluefish.

Zone[1]		PCB	%fillet[2]	%PCB[3]	Ratio[4]	Lipid
TD	1	1.12 ± 0.58	12.5	11.6	$0.93^{c,d}$	10.2 ± 7.4
	2	1.19 ± 0.58	15.1	14.8	0.98^{c}	9.0 ± 4.4
	3	0.96 ± 0.42	11.4	9.2	$0.81^{d,e}$	8.1 ± 3.8
CD	4	0.80 ± 0.42	7.9	5.2	$0.66^{f,g}$	6.2 ± 3.0
	5	0.60 ± 0.32	3.6	1.8	$0.50^{h,i}$	4.7 ± 2.0
	6	0.51 ± 0.30	1.7	0.7	0.41^{i}	3.5 ± 1.5
TV	7	1.71 ± 0.69	9.6	13.9	1.45^{a}	13.9 ± 6.7
	8	1.79 ± 0.91	12.4	18.1	1.46^{a}	12.9 ± 5.7
	9	1.57 ± 0.91	12.0	15.4	1.28^{b}	12.3 ± 5.8
CV	10	0.92 ± 0.49	8.2	6.2	$0.76^{e,f}$	7.5 ± 3.7
	11	0.69 ± 0.31	3.9	2.2	$0.56^{g,h}$	5.0 ± 2.2
	12	0.53 ± 0.20	1.8	0.8	$0.44^{h,i}$	3.9 ± 1.5

[1]The total number of individual fish analyzed for each zone was 7; TD=trunk dorsal; CD=caudal dorsal; TV=trunk ventral; CV=caudal ventral.

[2]% fillet = (grams of fillet per zone) / (total grams of fillet) X 100.

[3]% PCB = (grams of fillet per zone) X (ug/g) / (total gram of PCB in fillet) X 100.

[4]Ratio = % PCB / % fillet. Zones with the same letters were accepted to be equal ($P < 0.05$; one way analysis of variance, mean group by Duncan test).

As expected, there was a direct correlation between the % lipid and PCB concentrations (ug/g) in the various zones within a specimen (r=0.99). For example, the ventral trunk had the highest lipid concentrations and also had the highest PCB concentrations. While, on the other hand, the caudal area had the lowest lipid concentrations and had the lowest PCB concentrations.

In Tables 2 and 3 are the summarized results for PCB, DDT and chlordane concentrations (ug/g for PCB and ng/g for DDT and chlordane) in trimmed and un-trimmed fillets. The mean reduction in PCB concentration for trimmed fillets was 27 % with a range of 14 to 49 %. PCB concentrations for trimmed and untrimmed fillets were 1.47 $\pm$ 0.52 and 2.04 $\pm$ 0.70 ug/g wet weight, respectively. Comparison of the two means using pooled t-test showed significant differences in PCB concentration ($P < 0.05$). The mean lipid concentration for trimmed fillets was 8.7 $\pm$ 1.9 compared to 12.0 $\pm$ 2.1 in untrimmed fillets. Additionally, reductions of 26 and 29 % were observed for DDT and chlordane, respectively. Equally important, the fillet yield after trimming was 72 %.

Our data have shown that trimming those portions of fillet which have the highest concentrations of lipid, such as the skin, dorsal fat, and the bellyflap significantly reduce PCB concentrations (ug/g) by 14 to 49 %, with a mean of 27 %. Similarly, other studies have shown reductions of PCB concentrations upon removal of skin and/or adipose tissues in other species of fish. In the case for striped bass (Morone saxatilis), White et al. (1985) using fish in the size class of 40 to 56 cm observed a 57 % reduction of PCB concentrations in trimmed fillets. In carp (Cyprinus carpio), Hora (1981) observed a 26 and 30 % reduction for PCB and lipid concentrations, respectively; and it was noted that removal of adipose tissues from the large sized fish had the least effect on PCB and lipid removal. For brown trout (Salmo trutta Linnaeus) and smallmouth bass (Micropterus dolomieui Lacepede), Skea (1979) observed reduced PCB concentrations with a range of 43 to 53 % for brown trout and 54 to 64 % in smallmouth bass. Even though similar reduction of PCB concentrations were observed in bluefish, carp, striped bass, brown trout, and smallmouth bass, caution should be used when extrapolating these data to other species of fish. For example, in the common catfish of India (Wallasgo attu) the distribution pattern of lipid is such that the highest concentration is found in the

caudal area (Jafri 1973). Further studies will be required to identify the distribution patterns of lipid and lipid soluble contaminants in other species of fish.

Table 2. Comparison of untrimmed and trimmed fillet for PCB (ug/g, wet weight) and lipid (%, wet weight).

	untrimmed		trimmed		% Reduction	
#	PCB ug/g	Lipid %	PCB ug/g	Lipid %	PCB[1]	Lipid[2]
1	0.95	9.5	0.69	6.2	27	35
2	2.37	10.1	1.35	6.6	43	35
3	2.66	11.1	1.68	7.2	37	35
4	3.11	10.4	1.60	6.5	49	38
5	2.37	11.9	1.65	8.8	30	26
6	1.47	12.1	1.13	10.4	23	14
7	1.67	14.9	1.28	10.6	23	29
8	1.39	12.0	1.11	9.4	20	22
9	1.86	12.3	1.29	7.9	31	36
10	2.07	16.2	1.44	11.4	30	30
11	2.66	10.8	2.11	8.5	21	21
12	1.25	10.9	0.82	7.3	34	33
13	2.40	11.3	1.98	9.2	18	19
14	2.13	14.5	1.68	11.8	21	19
15	2.02	11.0	1.59	7.3	21	34
16	2.61	14.3	2.24	11.6	14	19
17	2.92	14.1	2.13	9.5	27	33
18	1.38	10.1	1.00	6.3	28	38
19	0.93	14.8	0.76	11.6	18	22
20	3.42	12.5	2.59	9.2	24	26
21	1.18	7.9	0.85	5.7	29	29
Mean	2.04	12.0	1.47	8.7	27	28
S.D.	0.70	2.1	0.52	1.9	8	7

1% reduction = [((ug/g of PCB in trimmed fillet) (ug/g of PCB in untrimmed fillet) - 1] x 100.

2% reduction = [(% lipid in trimmed fillet) / (% lipid in untrimmed fillet) -1] x 100.

Table 3. Comparison of untrimmed and trimmed filet for DDT compounds and Chlordane compounds.

	untrimmed		trimmed		% Reduction	
#	DDT[1]	Chlordane[2]	DDT[1]	Chlordane[2]	DDT[3]	Chlordane[4]
1	80	17	55	12	31	29
2	158	38	90	25	43	34
3	213	41	169	41	21	00
4	185	37	102	24	45	35
5	197	22	123	13	38	41
6	147	39	125	25	15	36
7	167	36	116	26	31	28
8	206	37	139	22	33	41
9	268	49	169	35	37	29
10	277	55	224	42	19	24
11	275	59	230	56	16	05
12	145	22	97	15	33	32
13	324	68	311	39	04	43
14	242	24	227	20	06	17
15	187	20	115	9	39	55
16	477	58	353	44	26	24
17	452	168	316	94	30	44
18	211	38	133	18	37	53
19	92	11	80	12	13	-09
20	336	60	297	48	12	20
21	161	24	146	12	09	50
Mean	229	45	172	29	26	29
S.D.	103	32	87	15	13	17

[1]Total DDT = p,p'DDT + p,p'DDE + p,p'TDE (ng/g).

[2]Total chlordane = transchlordane + cischlordane (ng/g).

[3]% reduction = [(ng/g of DDT in trimmed fillet/ (ng/g of DDT in untrimmed fillet)-1] x 100

[4]% reduction = [(ng/g of chlordane in trimmed fillet/ (ng/g of chlordane in untrimmed fillet)-1] x 100

REFERENCES

Hora ME (1981) Reduction of polychlorinated biphenyl (PCB) concentrations in carp (Cyprinus carpio) fillets through skin removal. Bull Environ Contam Toxicol 26:364-366

Jafri Ak (1973) Fat and water distribution patterns in the flesh of the common cat-fish Wallago attu. Fishery Technology X(2):138-141
Sargent W, Boreman J (1984) Bluefish: Biology and management along the Atlantic coast. Report; April; 6 p. (Avail. from Nat Mar Fish Serv/NE Fish Cent, Woods Hole Lab, Woods Hole, Mass 02543)
SAS Institute (1985) SAS/STAT Guide for personal computers, version 6. Cary, North Carolina: SAS Institute Inc 378 p
Skea JC, Simonin HA, Harris EJ, Jackling S, Spagnoli JJ, Symula J, Colquhoun JR (1979) Reducing levels of mirex, aroclor 1254, and DDE by trimming and cooking Lake Ontario brown trout (Salmo trutta Linnaeus) and smallmouth bass (Micropterus dolomieui Lacepede). J Great Lakes Res 5:153-159
White RJ, Kim HT, Kim JS (1985) PCBs in striped bass collected from the Hudson river, New York, during fall, 1981. Bull Environ Contam Toxicol 34:883-889
Wilk SJ (1977) Biological and fisheries data on bluefish, Pomatomus saltatrix (Linnaeus). U.S. Nat Mar Fish Serv/Sandy Hook Lab Report No Technical Ser-11;56 p. (Avail. from Nat Tech Info Serv: PB-283 90714)
U.S. National Oceanic and Atmospheric Administration, U.S. Food and Drug Adminisrtation, U.S. Environmental Protection Agency. 1986. Report on the 1984-1986 federal survey of PCBs in Atlantic coast bluefish. Data report; March; 179 p. (Avail. from Nat Tech Info Serv: PB86-218070/XAB)
U.S. National Oceanic and Atmospheric Administration, U.S. Food and Drug Administration, U.S. Environmental Protection Agency. 1987. Report on the 1984-1986 federal survey of PCBs in Atlantic coast bluefish. Interpretive report; March; 76 p (Avail. from Nat Tech Info Serv: PB87-214672/XAB)

Received February 12, 1988; accepted June 4, 1988.