TEQ Calculations and Daily Intake Estimates Associated with PCBs in Shrimp from the U.S. Retail Market

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BACKGROUND AND OBJECTIVES

Polychlorinated biphenyls (PCBs) are ubiquitous global environmental contaminants and, as such, subsequently bioaccumulate in lipid-based matrices including human, bird, and fish tissue. For humans, the proximate source of up to 90% of PCB exposures is from the consumption of meat, dairy products, and lipid-rich aquatic foods, and the daily intake of these compounds results in long-term retention in fatty tissue.[1] The toxicity equivalence (TEQ) methodology traditionally utilizes mammalian-based toxicity equivalence factors (TEFs) to assess human intake and risk associated with PCBs. Similar to assessing human risk, TEFs can also be used to assess ecological risks to fish and birds. However, for fish, biochemical and toxicological effects of certain PCB congeners are substantially diminished compared to mammalian species so fish-TEFs are much lower than mammalian-TEFs.[2]

PCBs have been measured in fish and other seafood including catfish, char, crab, salmon, mussels, clams, and shrimp.[3-7] Previously, we measured levels of PCBs in 84 shrimp samples from different geographic origins and reported that concentrations did not vary significantly between wild-caught or farm-raised varieties or among shrimp from different continents.[8,9] Additionally, concentrations were all well below government-established tolerance levels for PCBs in edible food.[10] In the present study, we determined TEQs of dioxin-like PCBs in the shrimp using fish-TEFs and mammalian-TEFs, and we estimated human daily intake of PCBs associated with shrimp consumption.

MATERIALS AND METHODS

- Eighty-four shrimp samples (uncooked, warm-water) purchased from local fish markets, supermarkets, and grocery stores in the San Francisco and Sacramento areas between February and April 2009.
  - Twenty-seven percent (n=23) were wild-caught.
  - Sixty-nine percent (n=58) were farm-raised.
  - Four percent (n=3) were not identified as wild-caught or farm-raised.
- All samples were individually wrapped, labeled, and frozen on ice for shipment to the analytical laboratory.
- Samples analyzed by Vista Analytical Laboratory (El Dorado Hills, CA) for all 209 PCB congeners.
  - Used high-resolution gas chromatography-mass spectrometry according to the EPA Method 1668.
  - Multiple PCBs co-eluted, resulting in a total of 168 congeners/congener pairs for each sample.
  - Samples with non-detected concentrations assumed to have a value equal to the LOD divided by the square root of two.
- Summed PCB concentrations calculated for two groups of congeners.
  - Total PCBs: all 168 congeners/congener pairs.
  - DL-PCBs: 12 congeners with dioxin-like activity (PCBs 77, 81, 126, 169, 105, 114, 106/118, 123, 156, 157, 167, and 189).
- TEQs (fish and mammalian) calculated by summing the products of each of the dioxin-like congener concentrations and associated WHO-TEFs (Table 1).

MATERIALS AND METHODS CONTINUED

- Daily intake estimates calculated using mammalian-TEQs.
  - Used average daily ingestion rate of shrimp for the U.S. population (1.464 g/day) as reported in the USEPA Exposure Factors Handbook.[12]
  - Used standard body weight of 70 kg and exposure duration of 30 years.
  - Used exposure frequency of 365 days/year and averaging time of 70 years.
  - Values reported as pg/kg body weight/day for total PCBs and pg TEQ/kg body weight/day for dioxin-like PCBs, based on wet weight concentrations.
- All data analyses were conducted using Microsoft Excel and SAS software (Cary, NC).

RESULTS

- Highest maximum levels of fish-TEQ concentrations observed in North American shrimp (Table 2).

Table 2: Summary statistics for fish-TEQs by sample type and continent

	Fish-TEQ (pg/g)			
	N	Median	Range	95%tile
Wild-Caught	23	0.002	0.0004-0.004	0.003
Asia	3	0.001	0.001-0.003	0.003
North America	19	0.002	0.0004-0.004	0.004
South America	1	0.0009	--	--
Farm-Raised	58*	0.001	0.0004-0.005	0.004
Asia	43	0.001	0.0006-0.003	0.003
North America	7	0.002	0.0009-0.005	0.005
South America	7	0.001	0.0004-0.003	0.003

*Includes one sample from an unknown country of origin

- Farm-raised shrimp from North America had the highest median and maximum total PCB concentrations compared to all other samples (Table 3).
- Median TEQ for farm-raised shrimp from North America nearly twice the median for Asian farm-raised shrimp, and of all shrimp, the farm-raised variety had a wider TEQ concentration range, suggesting greater variability (Table 3).
  - Farm-raised shrimp had higher 95%tile TEQ measures among all regions compared to wild-caught shrimp.
  - Results are consistent with previously reported results of dioxin-like PCBs in shrimp from Catalonia, Spain (0.03 pg WHO-TEQ/g wet weight).[5]
- Consumption of wild-caught shrimp results in a higher intake of both dioxin-like PCBs and total PCBs relative to farm-raised shrimp (Figure 1).
  - Total PCBs were associated with much higher intakes overall than dioxin-like PCBs.
  - Wild-caught samples from Asia were associated with a higher intake of dioxin-like PCBs than farmed samples from Asia.
  - Farm-raised samples from Asia were associated with a higher intake of total PCBs than wild-caught samples from Asia.
  - Farm-raised samples from North America were associated with higher intake levels of both total PCBs and dioxin-like PCBs.

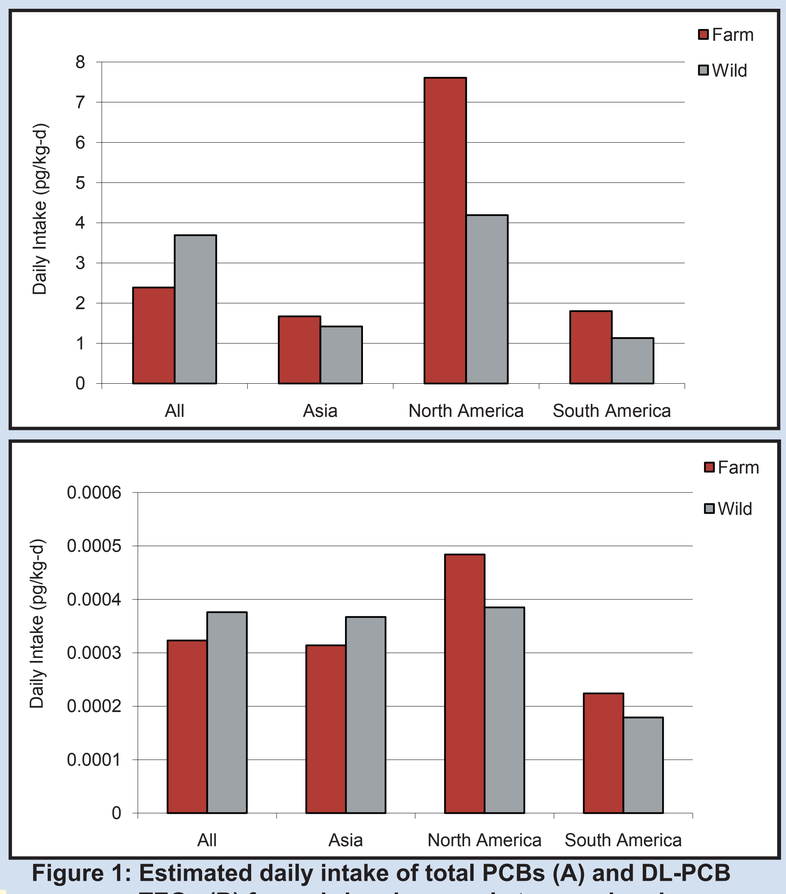

Figure 1: Estimated daily intake of total PCBs (A) and DL-PCB TEQs (B) from shrimp by sample type and region

CONCLUSIONS

- Fish-TEQ concentrations were very low because WHO-TEFs for fish differ from mammalian and bird TEFs since fish have a very low response to mono-*ortho* PCBs.[11]
- Estimated daily intake values are well below the WHO-provisional tolerable monthly intake level for non-cancer endpoints (2.3 pg TEQ/kg-d).[13]
- Previous analyses found that some samples from North America contained higher PCB concentrations relative to other shrimp[14]; however, estimates presented here indicate that those outliers do not contribute to any substantially elevated level of PCB intake from shrimp consumption.
- Studies have demonstrated that cooking practices often lower the quantity of PCBs in prepared foods.[15,16] Therefore, true PCB intake levels after adjusting for cooking are likely to be lower than levels reported here.

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REFERENCES

Available upon request.

Table 3: Summary statistics for total PCBs and DL-PCB TEQs by sample type and continent

	Total PCBs (pg/g)				TEQ (pg TEQ/g)		
	N	Median	Range	95%tile	Median	Range	95%tile
Wild-Caught	23	149.5	116.7-1648.3	1476.8	0.032	0.009-0.085	0.077
Asia	3	152.7	139.1-183.1	183.1	0.032	0.026-0.065	0.065
North America	19	149.5	116.7-1648.3	1648.3	0.035	0.009-0.085	0.085
South America	1	125.7	--	--	0.02	--	--
Farm-Raised	58*	177.6	108.2-2403.3	607.5	0.023	0.008-0.093	0.082
Asia	43	178.9	108.5-351.7	315.1	0.027	0.015-0.078	0.071
North America	7	225.6	137.2-2403.3	2403.3	0.049	0.017-0.093	0.093
South America	7	134.2	108.2-470.3	470.3	0.019	0.008-0.073	0.073

*Includes one sample from an unknown country of origin

Table 1: WHO-TEFs

	TEF (fish)	TEF (mammals)
PCB 77	0.0001	0.0001
PCB 81	0.0005	0.0003
PCB 126	0.005	0.1
PCB 169	0.00005	0.003
PCB 105	<0.000005	0.00003
PCB 114	<0.000005	0.00003
PCB 118	<0.000005	0.00003
PCB 123	<0.000005	0.00003
PCB 156	<0.000005	0.00003
PCB 157	<0.000005	0.00003
PCB 167	<0.000005	0.00003
PCB 189	<0.000005	0.00003