EXPOSURE ASSESSMENT FOR DIOXINS AND FURANS IN SEAFOOD AND DAIRY FOODS IN THE UNITED STATES, 1998-99

E. Jensen, R. Canady, and P. M. Bolger, US Food and Drug Administration, Center for Food Safety and Applied Nutrition, Washington, DC

Introduction

FDA regularly analyzes foods for the presence of industrial contaminants, including chlorinated dibenzo-p-dioxins and furans. Results of previous market basket surveys of dairy foods, fish and shellfish have been reported previously (Jensen and Bolger, 2000[1]). In 1998 and 1999 the agency analyzed samples of various finfish, shellfish, and dairy foods for the presence of 17 dioxin/furan congeners. Of these samples, a fraction of the finfish had dioxin-toxicity equivalent (TEQ) levels above one pptr. In 1998, the fraction of finfish that had levels greater than one pptr were: 5/20 salmon, 10/20 bass, and 0/10 Pollack. In 1999, the fraction of finfish that had levels greater than one pptr were: 5/20 salmon, 5/11 catfish, 11/16 bass, and 0/9 Pollack. Other foods in the survey had lower TEQ levels. In 1995-6, a similar survey showed that dioxin TEQ levels in 11/99 catfish had were greater than one pptr total TEQ basis, even when non-detects were treated as zeros. In that same survey, 0/17 samples each of tuna and cod had TEQs greater than one pptr.

Scope of the survey

Foods were selected for several reasons; the potential to be dietary sources of dioxins/furans, relatively high food consumption,[2] and/or because they have been dietary sources of dioxin/furans in the past. Salmon, crabmeat, pollack, lobster, crawfish, and bass were collected in both 1998 and 1999. In 1998, samples of mozzarella cheese, chicken eggs, and cream were also collected. In 1999, none of these "dairy" foods were collected, but scallops and catfish were added to the list of foods.

Analytical Methodology

Food samples were analyzed by the method "Quadrupole Ion Storage Mass Spectrometry/Mass Spectrometry Application To The Analysis Of All 17 2,3,7,8 Substituted Chlorodibenzo-p-Dioxins (Dioxins) And Chlorodibenzofurans (Furans) In Dairy Products And High Fat Foods," D. G. Hayward, Laboratory Information Bulletin No. 4084).[3] Limits of detection were reported for each congener in each food, and these values were used in the exposure assessment.

Estimates of Dioxin Contamination

Each food sample was analyzed for 17 dioxin/furan congeners. The analyzing laboratory reported both the measured concentration and limit of detection for each congener in each sample. These values were used with the toxicity equivalence factors (TEFs) developed by WHO (1998) to estimate TEQ concentrations in each sample. Because many of the reported values were non-detects, three estimates of dioxin-TEQ concentrations were derived using three values for the non-detects: zero, half the reported limit of detection (LOD/2), and the limit of detection (LOD). As expected for samples dominated by non-detects, the TEQs show a strong dependence on the value used to substitute for the non-detects.

The TEQs for each food are summarized in Table 1. The final column indicates the number of samples that had a TEQ greater than one pptr out of the total number of samples analyzed, when NDs were taken to be zero.

Table 1: Summary of average dioxin-TEQs, pptr				
1998 Dioxin Analyses:				
	ND=LOD	ND=LOD/2	ND=0	No. TEQ>1 at ND=0
Salmon	0.71	0.63	0.54	5/20
Bass	1.28	1.22	1.17	10/20
Crab	0.47	0.36	0.26	0/10
Crawfish	0.47	0.26	0.05	0/9
Lobster	0.49	0.31	0.13	0/8
Pollack	0.49	0.24	0.00	0/10
Eggs	0.29	0.17	0.05	0/20
Cream	0.32	0.27	0.22	0/19
Cheese	0.56	0.38	0.21	2/18
1999 Dioxin Analyses				
Salmon	0.63	0.51	0.39	5/19
Catfish	2.05	1.92	1.8	5/11
Bass	1.21	1.14	1.08	11/16
Crab	0.53	0.36	0.2	0/10
Crawfish	0.33	0.19	0.05	0/10
Lobster	0.41	0.21	0.02	0/9
Pollack	0.33	0.19	0.04	0/9
Scallops	0.33	0.16	0.00	0/11

Food Intake Calculations

Food intakes were calculated using the USDA 3-day 1989-92 Continuing Survey of Food Intakes by Individuals (CSFII) food intake survey. A commercial software package[4] was used with the raw USDA consumption survey results to derive the mean and standard deviation for the food intake on both a total sample and eaters-only basis, and the percentage of the population who are eaters. Per capita intakes are derived from the total sample results by applying weighting factors for region, gender, income, and other factors that reflect those characteristics in the actual population. Where adequate survey data were available, the software was used to generate a food intake distribution for eaters of a given food. The 90th percentile intake data from these distributions were taken to represent the intakes for "heavy" eaters. Consumption was estimated over all three days of the survey to obtain "chronic" intakes, although the use of short-duration surveys, such as the CSFII, likely overestimate food intakes.

Food intakes were calculated for the total US population, and are presented in Table 2. Intakes were calculated for eaters only (EO) and on a per capita (PC) basis. Intakes for all of the finfish were calculated as "foods" consumed, whereas the intakes of eggs, mollusks, and cheese were calculated as ingredients. No consumption of pollack or crayfish was reported in the survey; therefore, estimates of exposure to these foods could not be derived. Estimating the intake of cream as a food neglects its use in various foods as an ingredient and therefore likely underestimates intake of this food. In cases where a mean intake is reported, but no 90th percentile figure is presented, insufficient data were available in the survey to compute a distribution of intakes.

Table 2: Food intakes (g/p/d)			
		Mean	90th %ile
Salmon	PC	1.01	
	EO	51.49	82.05
Bass	PC	1.24	
	EO	48.54	98.40
Crab	PC	7.99	
	EO	53.19	97.54
Lobster	PC	0.19	
	EO	59.57	117.60
Eggs	PC	16.61	52.60
	EO	41.83	81.42
Cream	PC	1.39	21.21
	EO	49.16	
Cheese	PC	12.17	37.58
	EO	27.72	52.84
Mollusks	PC	2.12	
	EO	32.21	74.75

Method for Estimating Dioxin/furan Exposure

The following equation (equation 1) describes the estimated daily intake (EDI) of dioxin from the diet:

$$EDI = \sum I_j \times TEQ_j$$

where j sums across all foods, I_j is the consumption of a given food, and TEQ_j is the concentration of dioxin/furan in that food expressed in terms of 2,3,7,8-TCDD toxicity, or TEQ.

The TEQs reflect the relative toxicity of all of the dioxin and furan congeners present in a particular food in terms of 2,3,7,8-TCDD toxicity. Each TEQ_j (Table 2) is obtained by summing the products of the mean concentration of each (*i*th) dioxin congener ($C_{avg,i}$) and its TEF (equation 2).

$$TEQ_j = \sum_i C_{avg,i} \times TEF_i$$

By using the average concentration of each congener, we assume that eaters consume that food frequently enough so that the average concentration they experience over their exposure period (e.g., a lifetime) approximates the "true" average for that congener. The average concentration is the most appropriate concentration to use in estimating exposures over lengthy periods of time, particularly for chronic exposures.

The I_j values from equation 1 are either mean or 90^{th} percentile (food) intakes obtained from the food consumption distributions, and, when multiplied by the TEQ_j from equation 2, result in the dioxin-TEQ intake from each food. These in turn are summed to give the EDI. Dioxin/furan concentrations and intakes will refer to the values calculated on a TEQ basis.

Using these equations, estimates of TEQ exposures at the three different values for non-detects were derived and are presented in Tables 3 and 4. Mean dioxin exposure (pg/p/d) for consumers of various food are bounded by the values calculated at ND = zero and at ND = LOD. For the 1998 samples, these ranges were as follows (pg/p/d): salmon (28-37), bass (57 to 62), crab (14-25), lobster (8-30), eggs (2 to 12), cream (11 to 16), and cheese (6 to 16). Exposures based on the 1999 sampling data were as follows: salmon (20 to 32), catfish (130 to 148), bass (52 to 59), crab (11 to 29), lobster (1 to 24), and mollusks (0 to 11). Based on this assessment it is clear that for most of the foods in this survey the estimates of exposure are highly dependent on the treatment of NDs.

Table 3: 1998 Estimated dioxin intakes (pg/p/d)

ND=		LOD		LOD/2		Zero	
		Mean	90th %ile	Mean	90th %ile	Mean	90th %ile
Salmon	PC	0.72		0.64		0.55	
	EO	36.56	58.26	32.44	51.69	27.80	44.31
Bass	PC	1.59		1.51		1.45	
	EO	62.13	125.95	59.22	120.05	56.79	115.13
Crab	PC	3.75		2.87		2.08	
	EO	25.00	45.84	19.15	35.11	13.83	25.36
Lobster	PC	0.09		0.06		0.02	
	EO	29.19	57.62	18.47	36.46	7.74	15.29
Eggs	PC	4.82	15.25	2.82	8.94	0.83	2.63
	EO	12.13	23.61	7.11	13.84	2.09	4.07
Cream	PC	0.44	6.79	0.37	5.73	0.30	4.67
	EO	15.73		13.27		10.82	
Cheese	PC	6.82	21.04	4.62	14.28	2.56	7.89
	EO	15.52	29.59	10.53	20.08	5.82	11.10

Table 4: 1999 Estimated dioxin intakes (pg/p/d)

ND=		LOD		LOD/2		Zero	
		Mean	90th %ile	Mean	90th %ile	Mean	90th %ile
Salmon	PC	0.64		0.52		0.40	
	EO	32.44	51.69	26.26	41.85	20.08	32.00
Catfish	PC	2.73		2.55		2.39	
	EO	147.42	273.68	138.07	256.32	129.44	240.30
Bass	PC	1.50		1.41		1.34	
	EO	58.73	119.06	55.34	112.18	52.42	106.27
Crab	PC	4.23		2.87		1.60	
	EO	28.19	51.70	19.15	35.11	10.64	19.51
Lobster	PC	0.08		0.04		0.00	
	EO	24.42	48.22	12.51	24.70	1.19	2.35
Mollusks	PC	0.70		0.34		0.00	
	EO	10.63	24.67	5.15	11.96	0.00	

Reference

[1] Manuscript in preparation.

[2] For example, based on intake estimates from the 1987-88 Nationwide Food Consumption Survey (USDA).

[3] See also, D. G. Hayward, K. Hooper, and D. Andrezejewski, Analytical Chemistry, 71(1) (1999) 212-220

[4] TAS Diet Research Systems, TAS Diet Research, Inc., Arlington, VA, v. 3.51 (1997)