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THE CONCENTRATION AND DISTRIBUTION OF 2,3,7,8-DIBENZO-P-DIOXINS/-FURANS IN CHICKENS

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Abstract

The concentrations of the 2,3,7,8-Cl substituted dibenzo-p-dioxins/-furans (PCDDs/PCDFs) were determined in the edible tissues of whole chicken fryers and compared with the values found in their abdominal fat. The values are presented both on a whole weight basis and on a lipid adjusted basis for each tissue. While there is a marked difference in the concentration of the 2,3,7,8 dibenzo-p-dioxins in the edible tissues expressed on a whole weight basis, the lipid adjusted concentrations of the individual dioxins were not statistically different in the various tissues. This validates the use of lipid adjusted concentrations of 2,3,7,8 PCDDs/PCDFs in the abdominal fat for the determination of the presence of these compounds in different tissues.

INTRODUCTION

As part of the USEPA's Dioxin Exposure Initiative, the concentration of 2,3,7,8-Cl substituted dibenzo-p-dioxins/furans (PCDDs/PCDFs) were determined in a number of food items, including beef, pork and poultry in the United States^{1,2,3}. These surveys used statistically designed sampling strategies in order to derive a national average for these congeners in the various foods. From these averages an assessment could be made to determine the amount of PCDDs/PCDFs contributed through the diet.

During the analytical phase of the Survey of Dioxin-Like Compounds in Poultry, two commercially available whole fryer chickens were purchased to verify the significance of the analysis of abdominal fat rather than edible chicken tissue (e.g., breast, thigh) for the presence of PCDDs/PCDFs. It had been demonstrated in beef tissue samples⁴ and is generally accepted that lipophilic compounds are at higher concentrations in fat tissue and that the analyses of fat samples increase the probability of detection of these compounds when present at ultra low levels. The concentrations of these compounds in the tissues are calculated, the lipid content determined, and the results compared on a whole weight and lipid adjusted basis. This paper presents the results of the comparison of the concentrations of PCDDs/PCDFs in abdominal fat,

skin, thigh, breast, liver, and gizzard of whole fryer chickens.

Experimental

Samples: The two commercially available whole fryer chickens were purchased from a local supermarket in New Orleans, Louisiana in March, 1997. The two fryers weighed 2.32 and 2.24 kg and had been grown in the Louisiana/Arkansas area. The fryers were cleaned and quartered and the samples frozen until analysis. It was not certain that the livers and gizzards packaged within the fryers were actually the specific organs removed from the animals, only that they were from the same production lot processed at that time.

Analysis: The procedures used to analyze the chicken tissue samples for PCDDs/PCDFs were similar to the procedures used to analyze for these compounds in poultry fat samples. These procedures for the chicken tissues are described in Ferrario *et al*^{5,6}. These procedures were based on a modified version of USEPA Method 1613⁷. The percentage of lipids in the tissue samples was determined by lipid determination procedures described in USEPA Method 8290⁸. The average lipid contents for the abdominal fat, skin, thigh, liver, gizzard, and breast were 62.8%, 12.7%, 3.1%, 1.3%, 1.2%, and 0.5% respectively.

Approximately 12 g of abdominal fat, 15 g of liver, 25 g of gizzard, and 40 g each of skin, thigh, and breast were individually ground and homogenized, fortified with ¹³C recovery surrogates, and solvent extracted. The extracts were cleaned using a combination of acidified and basic silica gel, alumina, and carbon column chromatography. The final extracts were spiked with an internal standard and volume adjusted to 20 µl final volume prior to analysis. A 1-2 microliter sub-sample of the final extract was analyzed using a 60 meter DB5-MS® column by HRGC/HRMS. The KRATOS Concept® mass spectrometer was operated in the mass drift correction mode, and the native analyte concentrations were determined by isotope dilution. The samples were analyzed for the seventeen 2,3,7,8 PCDD/PCDF compounds which have toxicity equivalency to 2,3,7,8-TCDD.

The Limit of Detection (LOD) and Limit of Quantification (LOQ) for the PCDDs/PCDFs in the abdominal fat on a lipid basis were 0.05:0.10 part per trillion (ppt) for the tetras, 0.25:0.50 ppt for the pentas, 0.25:0.50 ppt for the hexas, 0.25:0.50 ppt for the heptas, and 0.50:1.00 ppt for the octas.

Results and Discussion

The results of the average concentrations of 2,3,7,8 PCDDs in the chicken tissues are presented in Table 1 on a whole weight basis and in Table 2 on a lipid adjusted basis. As expected, the concentration of the individual congeners, based on whole weight, decreased proportionally as the lipid content of the individual tissues decreased. The congeners present at the lowest concentration in the fat tissue were below the LODs for tissues with low lipid concentrations (e.g., liver, gizzard, breast). However, the concentrations of the detected congeners are very similar when normalized to the percent lipid of the individual tissues.

Table 1. Average Concentrations of 2,3,7,8 PCDDs in Chicken Tissues [ppt: whole weight]

Matrix	Fat	Skin	Thigh	Liver	Gizzard	Breast
2,3,7,8-TCDD	16.66	3.68	0.74	0.55	0.25	0.09
1,2,3,7,8-PeCDD	7.89	1.72	0.33	0.19	-	-
1,2,3,4,7,8-HxCDD	1.21	0.28	-	-	-	-
1,2,3,6,7,8-HxCDD	4.19	0.94	0.20	-	-	-
1,2,3,7,8,9-HxCDD	11.64	2.57	0.44	0.34	0.17	-
1,2,3,4,6,7,8-HpCDD	14.45	3.38	0.80	0.70	0.25	0.16
OCDD	183.13	45.65	10.24	9.99	2.73	2.01

Table 2. Average Concentrations of 2,3,7,8 PCDDs in Chicken Tissues [ppt: lipid adjusted]

Matrix	Fat	Skin	Thigh	Liver	Gizzard	Breast
2,3,7,8-TCDD	26.85	26.65	23.42	32.59	19.49	17.28
1,2,3,7,8-PeCDD	12.75	12.41	10.69	-	-	-
1,2,3,4,7,8-HxCDD	1.95	2.07	-	-	-	-
1,2,3,6,7,8-HxCDD	6.73	7.08	6.64	-	-	-
1,2,3,7,8,9-HxCDD	18.53	18.52	14.11	19.50	12.17	-
1,2,3,4,6,7,8-HpCDD	23.16	23.71	26.29	36.50	16.68	33.11
OCDD	295.26	375.98	329.97	523.18	190.07	423.60

In Table 3, the results of the analyses of current study for these two chickens are compared to the results of the analyses of fryer chickens in the US Survey of Dioxin-Like Compounds in Poultry³ and the results of the analyses of catfish samples from Arkansas⁹. In the

Survey of Dioxin-Like Compounds in Poultry, eighty poultry fat samples were analyzed of these forty-one were chicken fat samples. Two of the chicken fat samples had PCDD concentrations and congener profiles nearly identical to the two fryers of this study. The two survey samples, subsequently found to be contaminated, were determined to be outliers at the 95% confidence level by the Dixon and Grub Outlier Tests¹⁰ and, as such, did not represent a normal sample and were not used in the final US national averages.

Table 3. Average Concentrations of PCDDs from US Survey of Poultry (Chickens), Whole Fryer Chicken Samples, and Catfish [ppt: lipid adjusted]

Matrix	US Survey of Poultry (Chickens)	Whole Fryer Chickens (this study)	Catfish
2,3,7,8-TCDD	0.15	26.9	30
1,2,3,7,8-PeCDD	0.12	12.8	15
1,2,3,4,7,8-HxCDD	0.05	1.95	1.7
1,2,3,6,7,8-HxCDD	0.33	6.73	5.9
1,2,3,7,8,9-HxCDD	0.29	18.0	15
1,2,3,4,6,7,8-HpCDD	1.53	23.2	9.4
OCDD	5.31	295	57

The US national averages of PCDDs in chickens in Table 3 exclude those two contaminated chickens and represent the averages for the remaining thirty-nine samples. The concentrations of all the individual congeners detected in the two chickens of this study are higher than to the national average. This is most pronounced with respect to TCDD and OCDD congeners. Another characteristic feature that distinguishes this profile from that of the national average is that the concentration of the 1,2,3,7,8,9-hexachlorinated dibenzo-p-dioxins (HxCDD) is higher than the two other 2,3,7,8 Cl-substituted HxCDD congeners. This is an extraordinary finding as the 1,2,3,6,7,8 HxCDD is usually the dominant HxCDD congener found not only in chickens, but also in other environmental samples under normal exposure conditions. In addition, the concentrations of the PCDFs were much lower than expected from normal background exposure when compared to the elevated concentrations of the PCDDs. These profile characteristics were also observed by Cooper *et al*⁹ in catfish samples taken from the same area as the chickens. Further investigations have established that both the two fryer chickens of this

study, the two chickens that possessed elevated concentrations of PCDDs in the US Survey of Poultry (Chickens) and the catfish had been fed contaminated feed that subsequently has been removed from the market. The feed was contaminated by PCDDs in ball clay which was added to the soy meal component of the feed as an anti-caking agent.

The average TEQ for the thirty-nine noncontaminated chickens of the US Survey of Dioxin-like Compounds in Poultry was 0.64 pg/g (ppt) and the average for all total forty-one chicken samples, including the two contaminated chickens in the US Survey of Dioxin-like Compounds in Poultry was 1.77 pg/g (ppt). An earlier estimate of the TEQ concentration in chicken made by the EPA¹¹ was 1.3 pg/g (ppt). The average TEQ for the two chickens in this study was 37.4 pg/g (ppt). This TEQ is much higher than both the TEQ for the US Survey of Poultry and TEQs reported from Canada and Europe. Furst *et al*^{12,13} reported poultry concentrations of 1.4 and 2.3 ppt TEQ in Germany. Furst *et al*¹³ also reported a concentration of 2.6 ppt TEQ for poultry in Canada. Theelen *et al*¹⁴ reported a concentration of 1.65 ppt TEQ in the Netherlands. These average toxicity equivalences (TEQs) were based on lipid adjustment and not detected values equaling ½ LOD.

The elevated levels found in the abdominal fat of the whole fryer chickens indicated that the analyses of the other less fatty tissues yield proportionally similar concentrations based on the lipid content of the tissues, at least, for those congeners present at the high concentrations. The results of the concentrations of the other tissues verify the validity of using fat samples as a reliable indicator of the concentration of these congeners in other edible tissues.

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