EFFECTS OF COOKING ON LEVELS OF PCBs IN THE FILLETS OF WINTER FLOUNDER

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ABSTRACT

The consumption of contaminated fish has been shown to be a significant pathway for human exposure. Risk assessors often assume that humans are exposed to the levels of contaminants in edible tissue of fish measured prior to preparation and cooking. This assumption may lead to overestimation or underestimation of risk since a particular cooking method may remove or transform toxic constituents in the flesh. This paper presents and discusses the results of a study conducted to quantify the effect of preparation and cooking on PCB concentrations in the edible portion of winter flounder. The effects of broiling, pan frying, and deep frying in oil were tested on fillets from 21 fish. Deep frying in oil resulted in a 47% reduction in total PCB levels in fillet tissue, while pan frying and broiling did not result in a statistically significant difference in total PCB levels.

INTRODUCTION

Contamination of surface water and sediments by toxic chemicals is a concern in many areas of the United States. Certain organic compounds and metals may accumulate in the tissues of aquatic organisms posing a health threat to consumers. Exposure and risk assessments conducted to determine health risks associated with the consumption of aquatic species often assume that the levels of contaminants in the tissue remain unchanged after preparation and cooking. This assumption may lead to overestimation or underestimation of risk because removal or transformation of toxic constituents in the tissue may occur by thermal decomposition, volatilization, dissolution in aqueous tissue fluids or lipids that drip off the tissue, or extraction into cooking oil during preparation.

Polychlorinated Biphenyls (PCBs) are of particular interest because of their toxicity, their widespread presence, and their persistence in the environment. The effects of cooking on PCB levels and other contaminants have been studied by several authors. Some authors have found no significant changes in PCB concentrations, while others have reported both decreases and increases in PCB levels following cooking of fish muscle.[1,2,3,4,5,6,7,8]

The objective of this study was to quantify the effect of preparation and cooking on levels of PCBs found in fillets of winter flounder. The cooking methods used in the study were deep fat frying, pan frying with butter, and broiling.

METHODS

Twenty-one winter flounder were caught by otter trawl from New Bedford Harbor, Massachusetts on February 21, 1991. The intent was to collect fish that had been in the estuary for approximately 3 to 4 years before beginning their annual migration. Age classification was determined by length.

Sample preparation

Before the study began, store-bought winter flounder of comparable size were used to determine optimal filleting and cooking methods. No analysis were conducted with the store-bought fish. The initial processing of the fish consisted of filleting and sectioning the fillets. The weight and length of the fish were recorded for all fish before filleting.

A top and bottom fillet were obtained from each fish. Top and bottom fillets were assigned for precooking and cooking treatments in an alternating fashion to reduce bias which may result from the choice of fillet. The fillet used for cooking was cut on a dorsal-ventral plane into three subsamples of approximately equal size. The anterior (nearest the head) section was Section I, the middle section was Section II, and the posterior section was Section III. An equal number of the three different sections were used for each of the three cooking methods (i.e., seven of each section from the 21 fish). Pre- and post-cooking weights of the treatment sections were recorded to determine weight loss and precooking equivalent weights. Moisture and lipid content were determined on all raw samples.

Deep fried samples were cooked for approximately 1 min in 200 mL of pure vegetable oil in a fryer that had been preheated for 5 min. Pan fried samples were cooked for approximately 1 min per side in 1 tablespoon of lightly salted butter in a 9-in non-stick frying pan that had been preheated. Broiled samples were cooked for approximately 2 min on a broiling pan in an oven that had been preheated for broiling. All utensils were thoroughly cleaned between samples. Fresh cooking oil was used for each fish. Cooked samples were homogenized and stored until sample extraction.

Sample extraction and analysis

After thawing, approximately 5 to 25 g of tissue was removed. The sample were extracted three times and the extracts combined. The extract was then purified by gel permeation high-performance liquid chromatography (HPLC) and analyzed using a gas chromatograph with hydrogen as the carrier gas.

PCB congener concentration data were determined in nanograms per gram on a raw (precooked) wet-weight basis. The extraction sample wet weights were corrected to raw wet weight for the cooked samples, using pre- and post-cooking sample weight ratios from the same fish and cooked section. Samples were quantified relative to the surrogate compound dibromooctafluorobiphenyl (DBOFB). Samples were analyzed for total PCB concentrations and 18 PCB congeners.

To calculate the total PCB concentration, the average concentration of the 18 congeners in a "total PCB-mix" was determined for a 1:1 mix of Aroclors 1242 and 1254. This Aroclor composition is the approximate composition of the PCBs which were released in the New Bedford Harbor area where fish were collected.[9]

The equation used to determine the fractional change in PCBs resulting from cooking was derived by Skea et al. (2):

$$F=\frac{(C_r\times M_r)-(C_c\times M_c)}{C_r\times M_r}$$

where F = the fractional change in PCBs
C_r = concentration of PCBs in raw fillets
M_r = mass of raw fillet
C_c = concentration of PCBs in cooked fillets
M_c = mass of cooked fillet

A three-way analysis of variance (ANOVA) was performed to evaluate differences of cooking treatment. A one-way ANOVA was performed on treatment effects, and differences between cooking treatments evaluated with Fisher's Least Significant Differences (LSD) test.

The same approach was used to evaluate the effects of cooking on individual congeners. Cases in which a congener was less than the detection limit in the raw tissue were deleted from the data sets. When both the cooked and the raw fillet were below detection limits, the fractional change was recorded as 0%. When a congener was quantified in the raw fillet but was below detection in the cooked fillet, the fractional change was entered as 100%. This assumption will overestimate PCB reduction because a small change in congener concentration may have resulted in a less-than-detectable amount, but not complete removal. A reanalysis was done including those congeners for which cooked samples were below detection limits. This reanalysis involved congeners Cl_2(08), Cl_3(18), Cl_4(44), Cl_9(206), and Cl_{10}(209).

RESULTS

Deep-fried fillets showed approximately a 40% weight loss, apparently resulting from loss of water, while broiled and pan fried fillets showed a weight loss of approximately 15% and 7% respectively. The moisture content ranged from 79.5% to 85%. The lipid content for the uncooked fish ranged from 0.8% to 4.5% with an average of 1.8%.

The triplicate analyses of an equal mix of Aroclors 1242 and 1254 indicated that the 18 PCB congeners used in this study constitute approximately 58% of the total PCB. This relationship was then used to determined the total PCB concentration, as an equal mix of Aroclors 1242 and 1254 in the fish samples. This relationship was also determine using 17 PCB congeners, after excluding $Cl_7(170)$. The 17 congeners make up approximately 57% of the total PCB. Congener $Cl_7(170)$ was excluded because of interference in the instrumental analysis which could result in an unreliable quantification of this congener.

Total PCB concentration, based on 17 congeners, ranged from 0.014 to 4.0 µg/g wet weight in the precooked samples. The PCB congener distributions were similar for most fish; $Cl_5(118)$, $Cl_6(153)$, and $Cl_6(138)$ were the most abundant of the 18 congeners. The distribution of congeners in the fish looked more like the distribution in Aroclor 1254 alone, based on the relative amounts of PCB congeners by levels of chlorination.[10]

The Total PCB levels decreased 47% when fillets were deep fried (Table 1). This decrease in PCB concentrations was found to be significant ($\alpha = 0.05$). However, no statistically significant difference ($\alpha = 0.05$) was observed in total PCB levels in broiled and pan fried fillets. Fisher's Least Significant Differences test indicated that the deep-frying treatment was significantly different from the pan-frying and broiling methods.

Individual congeners were also evaluated for the effects of cooking on congener levels (Table 2). The analysis excluded those cases for which congener concentrations were found below detection limit in the raw or cooked samples. The t tests indicated a significant reduction of specific congener levels ranging from 42% to 74% for deep-fried fillets. Congeners $Cl_2(08)$, $Cl_3(18)$, $Cl_4(44)$, $Cl_9(206)$, and $Cl_{10}(209)$ were found below detection limit in some deep-fried fillet samples. In pan-fried fillets, congeners $Cl_5(105)$ and $Cl_5(118)$ had the only significant fractional increases of approximately 25% in congener level ($\alpha = 0.05$). Fractional increases in congeners $Cl_5(105)$, $Cl_5(118)$, $Cl_6(138)$, and $Cl_9(206)$ were also significant for broiled samples ($\alpha = 0.05$).

DISCUSSION

Results indicated a significant decrease in total PCB levels following deep frying. In contrast, pan frying and broiling did not result in a statistically significant difference in total PCB. The factors that contribute to changes in PCB levels in cooked fillets are complex. This study was designed to prevent any bias from position of the fillets by sectioning them into three subsamples. These variables may include total surface area of the fillet, thickness of the fillet, lipid content, and interactions of these variables with the cooking methods. Pan-fried fillets have less surface area exposed to air, which might reduce volatilization of PCBs compared with broiled fillets. The deep frying process creates unique cooking conditions that accelerate drying of the fillets compared with broiling and pan frying.

Zabik et al. (1982) suggested that extractability of PCBs was related to a high percentage of lipid in the tissue. Their early work with lake trout indicated significant reductions in total PCBs due to cooking when expressed on a mass basis. The lake trout had a high amount of lipid (20-30%) in the fillets. In contrast, carp used in their 1982 study had 7.7 ± 3.2% lipid. The winter flounder used in this study had an average lipid level of 1.8%. While increased lipid content in fish flesh may be associated with greater PCB losses during cooking, there are also data to the contrary. Trotter et al. (1989) reported increases in PCB levels in bluefish (11.8% lipid) following cooking. Smith et al. (1973) reported decreases in PCB levels in salmon following cooking, where precooked lipid levels ranged from 2.7% to 3.6%. Moreover, most weight loss following cooking is due to losses in moisture, either by vaporization or in drippings; there generally is not a significant change in lipid levels on a gravimetric basis following cooking. Deep frying, however, increases the measurable amount of lipid in cooked tissue by absorption of the cooking oil.[5]

It should also be emphasized that the range in PCB concentrations encountered in winter flounder fillets was very large. This variability would result in some statistical error. Nevertheless, deep frying appears to significantly reduce PCB levels. This reduction may be explained by the evaporation of water and PCBs from the fillets resulting from the high temperature of the cooking oil. Another possible explanation to this reduction may be that the cooking oil itself could be acting as an extraction solvent. This is, however, unlikely due to the short period of time that the fillets are in contact with the oil.

8. REFERENCES

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Table 1: Fractional Change in Total PCB Levels Resulting From Cooking

Cooking Method	Mean Fractional Change (SD)	t Test Probability
Broil	0.845 (SD=0.398) (+16.8%)	0.171
Deep Fry	1.605 (SD=0.475) (-47.3%)	0.0001
Pan Fry	0.457 (SD=0.457) (+15.3)	0.089

Table 2: Changes on Specific Congeners Resulting from Cooking

CONGENER	DEEP FRIED		PAN FRIED		BROILED	
	% change	Probability	% change	Probability	% change	Probability
Cl_2(08)	74	0.0001	4	0.8220	29	0.0694
Cl_3(18)	57	0.0001	21	0.2365	18	0.0547
Cl_3(28)	47	0.0001	-5	0.6541	-6	0.5258
Cl_4(44)	50	0.0001	11	0.1935	21	0.1069
Cl_4(52)	53	0.0001	1	0.9323	1	0.8957
Cl_4(66)	42	0.0003	-13	0.2700	-17	0.1133
Cl_5(101)	51	0.0001	-6	0.5019	-7	0.4098
Cl_5(105)	45	0.0001	-25	0.0259	-26	0.0153
Cl_5(118)	43	0.0001	-24	0.0407	-29	0.0085
Cl_6(128)	59	0.0001	-5	0.6124	-1	0.8854
Cl_6(138)	46	0.0001	-20	0.0839	-21	0.0344
Cl_6(153)	47	0.0001	-13	0.2301	-14	0.1635
Cl_7(170)	49	0.0001	-12	0.2329	-19	0.0785
Cl_7(180)	57	0.0001	2	0.8916	1	0.8802
Cl_7(187)	58	0.0001	4	0.6977	3	0.7028
Cl_8(195)	54	0.0001	-6	0.6215	-3	0.8134
Cl_9(206)	68	0.0001	21	0.0939	22	0.0471
Cl_{10}(209)	51	0.0073	10	0.4519	-2	0.9499