Bull. Environm. Contam. Toxicol. 21, 136-143 (1979)

Polychlorinated Biphenyls, Dieldrin and DDT in Lake Trout Cooked by Broiling, Roasting or Microwave[1]

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Recent data from the GREAT LAKES ENVIRONMENTAL CONTAMINANTS SURVEYS (1974, 1975) have shown that polychlorinated biphenyl (PCBs) concentrations in a particular type of lake trout (Salvelinus namaycush) caught in Lake Superior are excessively high. This type of trout is often referred to as fat trout or siscowets by local fishermen and have been found to have over 30 ppm of PCBs in the edible fillet. Fish with the highest levels have been caught off Grand Marais.

REINERT and coworkers (1972) reported broiling and frying reduced DDT concentrations in lake trout by 64-72%, however, WANDERSTOCK et al. (1971) summarized previous studies which showed broiling had little effect on DDT levels in trout and SMITH and coworkers (1973) reported baking and poaching of coho and chinook salmon resulted in minimal losses of PCBs and DDT compounds. The salmon in the latter study were on the start of the spawning run, however, and were relatively low in fat. Stewing and pressure cooking have been found to reduce PCBs in chicken (ZABIK 1974).

The objective of this study was to determine the effect of cooking fat trout fillets by broiling, baking and microwave on the levels of PCBs and other organochlorine pesticides. Sections of whole trout were also roasted with and without skin to determine the effect of removal of skin and the adhering fat on the levels of these contaminants in the edible flesh.

EXPERIMENTAL

Sixty pounds of fat trout were obtained frozen in the round from a commercial fisherman in Houghton, MI and were air freighted using dry ice to Lansing, MI. These fish had been caught off the Eastern side of the Keweenaw peninsula. These fish were thawed under gentle

[1]Published as Michigan Agricultural Experiment Station Journal Article No. 8376.

0007-4861/79/0021-0136 $01.60

running water sufficiently to measure and weigh and then six fish ranging from 1.2 to 1.7 kg and 52 to 55 cm were headed and gutted, tails and fins removed, skinned and then filleted. Each fillet was divided into thirds to provide head, middle, and tail sections. Fillets from the right side were analyzed raw while portions from the left side were assigned to be roasted, broiled, or cooked by microwave so that two head, middle and tail portions of the various fish were cooked by each method.

Ten trout ranging from 0.5 to 0.8 kg and 42 to 46 cm were used to study the effect of removal of the skin before baking. The trout were arranged in order of size and were then assigned to baking with or without skin to minimize size (and possible PCB level) variation. The center six-inch portions of each fish was used for cooking while both anterior and posterior one-inch portions were used for raw flesh analyses.

All pieces were frozen and held at -23°C before being thawed for 24 hr at 4-5°C before analyses or cooking.

COOKING PROCEDURES

Fillets were roasted on a rack in a 12 cm round aluminum pan in a household oven set at 177°C. The end point temperature of 75°C was determined by a recording potentiometer with thermocouple inserted in the center of the thickest portion of the fillet portion. Whole pieces with and without the skin were also roasted at 177°C to an internal temperature of 75°C. Removing the skin and associated fat reduced the total raw weight by an average of 21%.

Fillets were broiled to an internal temperature of 75°C by placing the fillet on a rack in a 12 cm round aluminum pan which was located so that the fish was 9.5 cm from the broiler source operating at 288°C.

Fillets were cooked in 12 cm round Pyrex glass pans covered with plastic food wrap in a household microwave (2450 MHz) operating at high for 0.75 to 2.0 min. To prevent a build up of steam pressure, a few 1 inch splits were made in the plastic film. Times were varied after preliminary trials to compensate for differences in portion size to obtain a similar degree of doneness as used for the other cooking methods.

Total, volatile and drip losses were calculated for all cooking methods.

PCBs AND PESTICIDE ANALYSES

Only edible flesh was analyzed for PCBs and pesticides. For raw whole fish pieces, edible flesh accounted for an average of 85% of the one inch slices while the remaining was bone and skin. For samples cooked with skin, the edible flesh accounted for an average of 80% of the sample while for samples cooked without skin, the average edible flesh was 94% of the total piece. Duplicate raw and cooked samples were treated to hexane-acetone extractions, acetonitrile partitioning, and florisil-celite column cleanup according to the procedures outlined by YADRICK et al. (1972). An aliquot of the hexane was dried under vacuum at 70°C to estimate fat. Following the final concentration, PCBs, dieldrin, and DDT were quantitated using a Tracor 560 gas chromatograph (GLC) equipped with a ^{63}Ni electron capture detector. The column for GLC was a Pyrex column, 1.83 m long x 4.0 mm id, packed with 3% OV-1 on 80/100 mesh H.P. Chromosorb W. The carrier gas was nitrogen with a flow rate of 40 ml/min. Temperatures at the injection port, column, and detector were 230, 190 and 300°C, respectively. Standards were prepared with 99 + % pure recrystallized dieldrin, p,p' DDT, and p,p'DDE as well as Aroclor 1254 in nanograde hexane. Quantitations were based on peak area for pesticides while the area of five peaks were used to quantify the PCBs. Standards were run at the beginning of every day and after every 8 or 9 samples. Presence of these residues was confirmed by mass spectrometric analyses. Mass spectrometric analysis was on a pool of all extracted samples from each lake. A Beckman GC-65 gas chromatograph interfaced with a DuPont 21-490 mass spectrometer was used. The mass spectra were obtained at an ionizing voltage of 70 eV with a source temperature of 210°C.

PCBs and pesticides were expressed on an edible tissue and fat basis. In addition, the total micrograms of these compounds in the cooked tissue was compared to that in the corresponding raw tissue to calculate recoveries of these compounds. Cooking losses as well as PCBs and pesticides in edible tissue and in fat were analyzed for variance.

RESULTS AND DISCUSSION

Broiling, Roasting and Cooking Fillets by Microwave

PCBs varied considerably among the six fish used to study the effect of broiling, baking, and microwave on residues in fillets ranging from 1.0 to 10.7 ppm in the raw edible flesh. This fish variation resulted in high standard deviations for all the PCB and pesticide data (Table 1).

TABLE 1

PCBs, dieldrin and DDT compounds in the edible flesh of fillets cooked by broiling, roasting or microwave.

Cooking Method	State	PCBs 1254	Dieldrin	DDT Compounds
		ppm	ppm	ppm
Broiled	Raw	3.8±1.7[a]	0.13±0.08	0.12±0.03
	Cooked	3.6±0.6	0.08±0.08	0.09±0.02
Roasted	Raw	4.6±3.2	0.11±0.08	0.11±0.03
	Cooked	3.9±3.6	0.11±0.08	0.08±0.02
Microwave	Raw	4.8±3.5	0.15±0.10	0.12±0.06
	Cooked	4.0±2.8	0.09±0.08	0.06±0.04

[a] Means and standard deviations of the mean of duplicate samples from each of six fish. Wet weight ppm based on raw wet weight and cooked wet weight, respectively.

Total cooking losses varied significantly ($p<0.05$) for the fillets that were broiled, baked or cooked by microwave. Fillets that were baked or broiled had cooking losses of 18% which were higher than for those cooked by microwave which were 11%. Average cooking times were 25 min for roasting, 6 min for broiling, and 1 min for microwave. Drip losses which would be primarily fat also differed significantly ($p<0.05$) being 6.1% for fillets broiled, 4.0% for fillets cooked by microwave and 2.0% for fillets baked. Volatile losses were 16% for fillets baked, 13% for fillets broiled and 7% for fillets cooked by microwave. Lower volatile losses for fillets cooked by microwave accounted for

the lowest total cooking losses with this method and may be related to the relatively short cooking time.

Cooked fillets had significantly less PCBs ($p<0.05$), dieldrin ($p<0.01$) and DDT compounds ($p<0.01$) than raw when these compounds were expressed on a whole tissue basis (Table 1). Only the level of PCBs were high in these fish with some values exceeding the current FDA tolerance of 2.0 ppm in raw edible fish. When these contaminants were expressed on a fat basis, cooking resulted in very highly significant reductions for all three contaminants (Table 2).

TABLE 2

Fat and contaminants expressed on a fat basis in the flesh of fillets cooked by broiling, roasting or microwave.

Cooking Method	State	Fat	PCBs 1254	Dieldrin	DDT Compounds
		%	ppm	ppm	ppm
Broiled	Raw	29.1±12.3[a]	23.6±11.6	0.41±0.32	0.48±0.19
	Cooked	29.7±1.1	14.1±7.9	0.26±0.18	0.29±0.12
Roasted	Raw	25.0±8.3	19.7±12.7	0.44±0.22	0.45±0.17
	Cooked	27.8±6.9	13.8±10.2	0.37±0.23	0.32±0.13
Micro-wave	Raw	26.4±7.6	16.6±8.9	0.61±0.49	0.43±0.15
	Cooked	26.5±8.5	14.0±7.1	0.39±0.33	0.21±0.18

[a] Mean and standard deviation of the mean of duplicate samples from each of six fish.

Despite the differences noted in cooking parameters broiling, roasting or cooking by microwave did not significantly affect the level of PCBs, dieldrin, or DDT compounds found in the cooked fillet. This was true whether the contaminants were expressed on a whole tissue (Table 1) or fat (Table 2) basis. The fat content of the fish remained fairly constant with cooking (Table 2) indicating that the loss of fat during cooking was proportional to the moisture loss.

Since both fat and moisture is lost during cooking, total micrograms of these contaminants in the cooked as compared to the raw piece was used to calculate percentage recoveries (Table 3). Broiling reduced PCBs by an

Table 3

Total micrograms of PCBs, dieldrin and DDT compounds in the edible fillet pieces cooked by broiling, roasting, or microwave.

Cooking Method	State	PCBs 1254	Dieldrin	DDT Compounds
		µg	µg	µg
Broiled	Raw	824[a]	21.1	17.8
	Cooked	390	10.9	10.8
Roasted	Raw	564	25.8	13.0
	Cooked	372	19.4	9.1
Microwave	Raw	595	14.9	21.7
	Cooked	442	7.9	9.7

[a] Mean and standard deviation of the mean for duplicate samples from each of six fish.

average of 53%, dieldrin by an average of 48% and DDT compounds an average of 39%. Roasting reduced PCBs by an average of 34%, dieldrin by an average of 25% and DDT compounds by an average of 30%. Cooking fillets by microwave reduced PCBs by an average of 26%, dieldrin by an average of 47% and DDT compounds by an average of 54%. Although there were not significant differences in these values due to cooking method, broiling did bring about the greatest reduction in PCBs and dieldrin.

Trout Roasted With and Without Skin

As expected from their smaller size, the trout used to study the effect of roasting with and without skin had lower levels of PCBs, dieldrin, and DDT compounds (Table 4). PCB levels were still considerably higher than were dieldrin or DDT compounds but the presence or absence of skin during roasting did not affect the level of these compounds in the cooked flesh. This was true when the PCBs, dieldrin and DDT compounds were expressed on whole tissue (Table 4) or fat (Table 5) basis.

Removing the skin before roasting significantly ($p<0.05$) affected total and volatile losses but not drip losses. Trout roasted without the skin had

Table 4

PCBs, dieldrin and DDT compounds in the edible flesh of whole trout pieces roasted with and without skin.

Roasting Condition	State	PCBs 1254	Dieldrin	DDT Compounds
		ppm	ppm	ppm
With skin	Raw	1.82±0.85[a]	0.04±0.01	0.09±0.03
	Cooked	1.17±0.58	0.03±0.01	0.05±0.02
Without skin	Raw	1.87±1.47	0.03±0.01	0.08±0.03
	Cooked	1.34±1.22	0.02±0.01	0.04±0.01

[a] Mean and standard deviation of the mean for duplicate samples from each of five fish.

Table 5

Fat and contaminants expressed on a fat basis of whole trout pieces roasted with and without skin.

Roasting Condition	State	Fat	PCBs 1254	Dieldrin	DDT Compounds
		%	ppm	ppm	ppm
With skin	Raw	18.1±5.3[a]	10.8±9.6	0.25±0.10	0.52±0.27
	Cooked	18.7±5.4	7.7±7.2	0.15±0.08	0.28±0.12
Without skin	Raw	16.1±5.4	10.6±5.1	0.22±0.09	0.55±0.29
	Cooked	15.1±5.9	7.3±6.3	0.13±0.08	0.27±0.12

[a] Mean and standard deviation of the mean for duplicate samples from each of five fish.

average total cooking losses of 17.0%, volatile losses of 15.6% and drip losses of 1.4% while trout roasted with the skin had average total cooking losses of 10.6%, volatile losses of 10.0% and drip losses of 0.6%. Baking time was unaffected by skin removal averaging 35.6 min for trout roasted without skin as compared to 35.2 min for trout roasted with skin. Fat level was not significantly affected by roasting per se or method of roasting (Table 4). Fat levels were lower in these smaller fish than in the fillets used for broiling, roasting, and cooking by microwave (Table 2). Fat levels of 50% and more have been reported for this type of fish (GREAT LAKES ENVIRONMENTAL CONTAMINANTS SURVEY 1975).

Total micrograms for trout pieces roasted with and without skin are summarized in Table 6.

Table 6

Total micrograms of PCBs, dieldrin, and DDT compounds in the edible portion of whole trout pieces roasted with and without skin.

Roasting Condition	State	PCBs 1254	Dieldrin	DDT Compounds
		µg	µg	µg
With skin	Raw	414[a]	9.2	18.4
	Cooked	249	5.0	9.8
Without skin	Raw	415	7.0	16.9
	Cooked	208	3.0	7.2

[a] Mean of five pieces.

Roasting trout pieces without skin resulted in an average of 50% loss of PCBs, 57% of dieldrin, and 57% of DDT compounds while roasting trout pieces with skin resulted in an average of 40% loss of PCBs, 45% of dieldrin and 47% of DDT compounds from the edible flesh. Although these differences are not statistically significant, it can certainly be recommended to remove the skin and associated fat before cooking this type of fish.

Therefore, cooking significantly reduced PCBs, dieldrin, and DDT in fillets and roasted trout pieces. Although the losses found in the current study were less than the 64-72% loss of DDT in broiled and fried lake trout reported by REINERT et al. (1972), there were greater losses than had been found by SMITH et al. (1973) or WANDERSTOCK et al. (1971). Losses of PCBs ranged from 26 to 70%, dieldrin from 25 to 57%, and DDT compounds from 30 to 57%. Losses were greatest for broiled fillets and for whole pieces roasted without the skin.

REFERENCES

GREAT LAKES ENVIRONMENTAL CONTAMINANTS SURVEY: Michigan Department of Natural Resources, Lansing, MI (1974)

GREAT LAKES ENVIRONMENTAL CONTAMINANTS SURVEY: Michigan Department of Natural Resources, Lansing, MI (1975)

REINERT, R. E., D. STEWART and H. L. SEAGRAN: J. Fish. Res. Bd. Canada 29, 525 (1972)

SMITH, W. E., K. FUNK and M. E. ZABIK: J. Fish Res. Bd. Canada 30, 702 (1973)

WANDERSTOCK, J. J., W. W. ISKAT, W. H. GUTENMANN, and D. J. LISK: N. Y. Fish Game J. 18, 70 (1971)

YADRICK, M. K., K. FUNK and M. E. ZABIK: J. Agr. Food Chem. 19, 491 (1971)

ZABIK, M. E.: Poultry Sci. 53, 1785 (1974)