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Polychlorinated Biphenyl Reduction in Lake Trout by Irradiation and Broiling[1]

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The GREAT LAKES ENVIRONMENTAL CONTAMINANTS SURVEYS (1974, 1975) have concluded that excessive concentrations of polychlorinated biphenyls (PCBs) are present in a specific species of lake trout (Salvelinus namaycush). Over 30 ppm of PCBs have been detected in the edible fillet of this fat trout.

ZABIK et al. (1979) reported that PCBs in lake trout were reduced by an average of 53% by broiling; 34% by roasting; and 26% by microwave cooking. SMITH et al. (1973) reported minimal losses of PCBs and DDT compounds when baking and poaching coho and chinook salmon. Stewing and pressure cooking have been found to reduce PCBs in chicken (ZABIK 1974).

MERRILL et al. (ANON 1977, 1978) reported that low concentrations of PCBs in water can be made water soluble by bombardment with high speed electrons. Dosages ranged from 400 kilorads to 5 megarads depending on the type of PCB compound present.

The objective of this study was to determine the effect of gamma irradiation combined with broiling on the levels of PCBs in lake trout fillets.

EXPERIMENTAL

Fifty pounds of eviscerated, frozen lake trout were obtained from a commercial fisherman in Hancock, MI and were air-freighted in dry ice to Lansing, MI. The fish were thawed under refrigerated temperatures (4-5^{O}) and were measured, weighed, and coded. Ten fish ranging in size from 0.8 to 1.2 kg and 45 to 52 cm were headed, tails and fins removed, skinned, then filleted. Each fillet was divided in half to provide head and tail sections. One inch sections from the anterior and posterior were reserved and used for raw flesh analyses.

Prior to irradiation, the fillets were weighed and frozen to -23^{O}C, submerged in liquid nitrogen, and packed in dry ice to prevent thawing. All fillets were given a pasteurization dosage of 1000 kilorads using a Cobalt-60 source. Fillets from the right side were irradiated then analyzed raw; while portions from the left side were irradiated, broiled, then analyzed. All

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pieces were frozen and held at -23°C before being thawed for 24 hours at 4-5°C prior to analyses after cooking.

Cooking Procedures

Fillets were broiled to an internal temperature of 75°C by placing each fillet on a rack in a 12-cm diameter aluminum pan which was located so that the sample was 16.5 cm from the broiler source operating at 288°C. The end point temperature of 75°C was determined by a recording potentiometer with a thermocouple inserted in the center of the thickest part of the fillet.

Thaw losses were calculated for all fillets, while total, volatile, and drip losses were computed for the broiled fish.

PCBs Analyses

Only edible flesh was analyzed for PCBs. Duplicate raw, irradiated, and irradiated cooked samples from each fish were treated separately 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 lthe final concentration, PCBs were quantitated by gas chromatographic analyses using a Tracor 560 gas chromatograph (GLC) equipped with a ^{63}Ni electron capture detector and interfaced with a Digital PDP-8e-Pamila GC data system. The column for the GLC was a Pyrex column, 1.83 m x 4.0 mm ID., packed with 3% OV-1 on 80/100 mesh Chromosorb W H.P. The carrier gas was nitrogen with a flow rate of 40 ml/min. Temperatures at the injection port, column and EC detector were 230, 190, and 300°C, respectively. Standards were prepared with Aroclor 1254 in nanograde hexane.

Quantitations were based on the area of five peaks for the PCBs. Standards were run at the beginning of every day and after every 9 samples.

PCBs were expressed on an edible tissue and fat basis. In addition, total micrograms of these compounds in the cooked tissue were compared to that in the corresponding irradiated and raw tissues to calculate the recoveries of these compounds. Percentage distribution of the PCB isomers were also calculated. Cooking losses as well as PCBs in edible tissue and in fat were analyzed for variance.

RESULTS AND DISCUSSION

The relatively large standard deviation reported for the solids and fat on a wet weight and dry weight basis was partially due to the variation in whole fish size. The fish weighed 0.9 $\pm$ .16 kg and measured 47.9 $\pm$ 2.4 cm in length. PCBs in the raw fillets varied from 1.0 to 3.1 ppm on a wet weight basis. Broiled fillets exhibited total cooking losses of 9.5 $\pm$ 2.9%. Drip losses which were primarily fat accounted for 1.01 $\pm$ 0.50%. Volatile losses were recorded at 8.49 $\pm$ 2.70% for the broiled fillets. Fat reported on both a wet and dry basis decreased as the samples were cooked. The amount of fat present in the raw samples on a dry basis was significantly ($p \leq .05$) greater than that detected in the samples which had been irradiated and broiled (Table 1).

TABLE 1
Solids and fat expressed on a wet and dry weight basis in the edible flesh of fillets irradiated and cooked by broiling[1].

State	Solids	Fat	
		Wet Basis	Dry Basis
Raw	35 ± 4	16 ± 3[a]	45 ± 6[a]
Irradiated	36 ± 4[ab]	14 ± 2[a]	40 ± 6[ab]
Irradiated and Broiled	38 ± 3[b]	14 ± 2[a]	38 ± 4[b]

1 Values in each column with the same superscript are not significantly different at $p \leq .05$ (DUNCAN 1957). Mean and standard deviation of the mean for duplicate samples from each of ten fish.

In some raw flesh samples analyzed, the PCBs level exceeded the current FDA tolerance of 2.0 ppm in raw edible flesh. Irradiated and broiled fillets exhibited significantly less PCBs than raw samples when these compounds were expressed on a wet basis, fat basis, and solids basis (Table 2). The reduction

TABLE 2
PCBs expressed on a wet, fat, and solids basic in the edible flesh of fillets irradiated and cooked by broiling[1].

State	ppm PCBs expressed on		
	Wet Basis	Fat Basis	Solids Basis
Raw	1.8 ± 0.7	11.5 ± 4.7	5.1 ± 2.2
Irradiated	1.2 ± 0.4[a]	8.5 ± 3.3[a]	3.2 ± 1.3[a]
Irradiated and Broiled	1.2 ± 0.4[a]	8.6 ± 3.0[a]	3.2 ± 1.1[a]

1 Values in each column with the same superscript are not significantly different at $p \leq .05$ (DUNCAN 1957). Mean and standard deviation of the mean for duplicate samples from each of ten fish.

in PCBs by irradiation and broiling was not significantly less than that exhibited in the fillets which were only irradiated ($p \leq .05$).

Since fat and moisture are lost during cooking, total micrograms of PCBs in the irradiated as well as the irradiated and broiled samples were compared to the raw piece to calculate percentage loss (Table 3).

Total micrograms of PCBs were lowest in the samples which were both irradiated and broiled. PCBs detected in the irradiated fillets and those both irradiated and broiled were not significantly

TABLE 3
Total micrograms and percent loss of PCBs in the edible flesh of fillets irradiated and cooked by broiling[1].

State	PCB 1254 µg	Percent Loss
Raw	140 ± 70	-
Irradiated	90 ± 40[a]	38
Irradiated and Broiled	80 ± 30[a]	43

1 Values in each column with the same superscript are not significantly different at $p \leq .05$ (DUNCAN 1957). Mean and standard deviation of the mean for duplicate samples from each of ten fish.

different at the $p \leq .05$ level. However, the percent loss of PCBs was slightly higher in the fish samples which were both irradiated and broiled.

The percentage distribution of PCBs gas chromatograph peaks are illustrated in Table 4. The area under peak number 1 was reduced by both the irradiation and irradiation and broiling treatments. The area under peak number 2 was significantly reduced with irradiation but not with the irradiation/broiling treatment. The area under peak number 3 was not significantly decreased with either the irradiation or the irradiation/ broiling procedures. The area under peak number 4 exhibited an increase with the two treatments. This increase was not significant between the irradiated and irradiated/broiled samples at $p \leq .05$. The area under peak number 5 increased with the two treatments and this increase was not significant. These peaks represent different chlorinated biphenyl compounds which vary in the amount of chlorine present.

KAHN and associates (1976) reported that lower chlorinated biphenyls are being formed as a result of breakdown of higher chlorinated biphenyls and there is a constant change taking

TABLE 4

Percentage distributions of PCBs gas chromatograph peaks in the edible flesh of fillets irradiated and cooked by broiling[1].

Peak	State		
	Raw	Irradiated	Irradiated and Broiled
1	21 ± 5	17 ± 4[a]	15 ± 4[a]
2	21 ± 5	13 ± 2	18 ± 7[a]
3	19 ± 6[a]	16 ± 11[a]	18 ± 11[a]
4	22 ± 6	36 ± 9[a]	32 ± 8[a]
5	16 ± 6[a]	18 ± 4[a]	17 ± 7[a]

[1] Values in each row with the same superscript are not significantly different at $p \leq .05$ (DUNCAN 1957). Mean and standard deviation of the mean for duplicate samples from each of ten fish.

place in the chlorinated biphenyls during the process of radiation. Probable components of four of these peaks have been identified from data of WEBB and McCALL (1971) as 2,3,6,2',5'-pentachlorobiphenyl for peak 1; 2,3,6,2',3'-pentachlorobiphenyl for peak 2; 2,4,5,2',3',6'-hexachlorobiphenyl for peak 4; and 2,4,5,2',4',5'-hexachlorobiphenyl for peak 5. The reduction in the proportion of the lower chlorinated peaks following irradiation may be due to more of these components becoming water soluble, thus being lost in greater proportion.

In conclusion, irradiated samples exhibited significantly lower levels of PCBs ($p \leq .05$). The combination of irradiation and broiling did not significantly reduce the levels of PCBs in trout fillets when compared to the samples which were irradiated only. Losses of PCBs were 38% in the irradiated trout fillets and 43% in the irradiated and broiled samples. These losses were slightly less, however, than those reported for broiling alone by ZABIK et al. (1979).

REFERENCES

ANON: Chem. Eng. News 59, 2, 25 (1977).

ANON: Chem. Eng. News 56, 47, 24 (1978).

DUNCAN, D. B.: Biometrics 13, 164 (1957).

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).

KHAN, M. A., A. F. NOVAK, and R. M. RAO: J. Food Sci. 41, 262 (1976).

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

WEBB, R. G., and A. C. McCALL: 162nd American Chemical Society Meeting, Washington, DC (1971).

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

ZABIK, M. E., P. HOOJJAT, and C. M. WEAVER: Bull. Environ. Contam. Toxicol. 21, 136 (1979).