TECHNICAL NOTES

Fate of Polychlorinated Biphenyls in Dairy Products Processed from the Milk of Exposed Cows

Abstract

Two actively lactating Jersey cows were given orally 10 and 100 mg/kg of polychlorinated biphenyls as a single dose. The milk was collected and Cottage cheese, whey, cream, skimmilk, and nonfat dry milk were made. Concentrations and metabolic forms of polychlorinated biphenyls were determined in the whole milk and in the processed dairy products. Metabolic forms of these biphenyls were not significantly altered by various processes. Heating skimmilk substantially decreased total polychlorinated biphenyls. Distribution of polychlorinated biphenyls in the prepared milk products indicates a strong predilection of them for the lipid phase.

Introduction

Polychlorinated biphenyls (PCB) are used industrially in the manufacture of resins, rubbers, paints, waxes, varnishes, lubricants, hydraulic fluids, heat-transfer media, etc. (1, 6). They are also used for dust prevention, moisture proofing, sealing and impregnation, and vapor suppression to prolong insecticide kill-life (1). Polychlorinated biphenyls incorporation into pesticide formulations increases the toxicity of dieldrin and DDT (11).

Polychlorinated biphenyls have been implicated as environmental contaminants of wildlife and fish in Europe (7, 8) and North America (2, 16) and appear to be ubiquitous (5, 16). They have been reported as being powerful inducers of hepatic enzymes which degrade estradiol (16) and of possessing an antiandrogenic-like effect (13). Poisoning among the general population of western Japan by the ingestion of rice bran oil contaminated with PCB, involving 600 patients was reported by Kuratsune (9). The contamination of nuts with PCB during storage and transportation was described by Bailey et al. (3). Their presence in human adipose tissue was reported by Biros et al. (4). Platonow et al. (14) reported the occurrence of PCB residues in the milk, urine, and some tissues of bovines exposed to environmental contamination.

Chlorinated hydrocarbon pesticides given to lactating animals are partially excreted in the milk, either per se or as metabolites (17), thus appearing in milk products (10). Polychlorinated biphenyls possess certain structural, physical, and chemical similarities to the DDT pesticides group (15). Thus, PCB share with the DDT group strong lipophilic properties, which result in prolonged persistence of PCB in milk and in fatty tissues of the body (14).

It was believed that PCB in dairy products might create a health hazard. Consequently, our preliminary study was undertaken to determine the fate of metabolically incorporated biphenyls in cow's milk and their distribution in dairy products processed from the milk.

Experimental Methods

Two actively lactating Jersey cows,[1] weighing 360 and 390 kg, were given orally 10 and 100 mg of polychlorinated biphenyls per kilogram of body weight as a single dose. They were given as Aroclor 1254,[2] dissolved in a small amount of olive oil and mixed with dairy concentrate. Milk from each cow was collected and pooled for four days and totalled 50.8 and 40.8 kg. Cream, skimmilk, Cottage cheese, and spray-dried nonfat dry milk were prepared from each lot of milk. Whey from Cottage cheese was also collected. Cream was prepared by warming the milk to 33 C and separating in a conventional separator. The skimmilk, without further heat treatment, was used to manufacture Cottage cheese. The coagulum was quickly formed with lactic acid and rennin rather than by the more conventional method of developing acid by lactic acid-producing bacteria. The curd was neither salted nor creamed. The skimmilk was heated to 70 C and held for 10 min before concentrating it to 30% solids in a Rogers laboratory evaporator at 45 C. The condensed skimmilk was heated to 50 C and spray-dried in a Swenson research spray drier with inlet air at 178 and outlet air at 80 C. Samples of all products, including whey, were tested for fat by the Mojonnier method (12). Control samples of whole milk and cream were collected for two consecutive days before the administration of PCB.

Polychlorinated biphenyls were extracted

[1] Animals and facilities were provided by the Ontario Department of Agriculture and Food.

[2] Aroclor 1254 was kindly supplied by Monsanto Canada Ltd., Toronto, Ontario.

TABLE 1. Concentrations of polychlorinated biphenyls and the percentages of fat in milk and milk products processed from the milk of cows given polychlorinated biphenyls.

Sample	Cow 1		Cow 2	
	10 mg PCB/kg		100 mg PCB/kg	
	PCB (mg/kg)	Fat (%)	PCB (mg/kg)	Fat (%)
Whole milk	3.893	5.05	36.099	5.65
Cream	23.321	17.50	262.872	22.60
Skimmilk	0.456	0.14	1.522	0.13
Heated skimmilk	0.165	0.14	0.427	0.13
Nonfat dry milk	1.677	1.65	4.838	1.51
Cottage cheese	1.486	1.50	5.930	1.20
Whey	0.284	0.03	1.621	0.04

from samples and consequently analyzed according to the method of Saschenbrecker and Ecobichon (18).

Results and Discussion

Analyses of controls failed to reveal any background PCB or any other substance capable of interfering with the analytical procedure.

Concentrations of PCB and percentages of fat in the dairy products are in Table 1. The amounts of biphenyls showed a predilection for the fat, since most PCB was in the cream and whole milk and least in the skimmilk and whey. The fat content of these samples decreased in the same order. However, the actual amounts of the biphenyls were not always proportional to the fat content. Polychlorinated biphenyls were proportional to the fat content in the whole milk and cream from both animals, and nearly proportional in the curd and nonfat dry milk from the animal having the lower dose. Whey from the milk of both animals contained proportionally more PCB per fat unit than any other sample.

It is of interest that milk from the animal receiving 100 mg of PCB per kilogram contained about 10 times more PCB than milk from the cow receiving only 10 mg/kg. More than a tenfold difference was found in the cream from the two animals. In the other samples there was no consistent correlation between the dose and PCB concentration except that the ratio was less than 10 to 1.

Heating skimmilk from each animal to 70 C and holding it for 10 min decreased PCB by two-thirds.

Sixteen distinct gas chromatographic fractions from all samples were numbered according to the code of Reynolds (15). Each fraction was expressed as a percentage of the whole. The data are in Table 2. The only significant change in the chromatograms, compared to that of the standard, occurred in the two samples of cream where Fraction 1 was significantly lowered.

From these data, the various processes used in our study did not contribute to significant changes in the percentage distribution of PCB fractions within the various dairy products. On the other hand, heating skimmilk substantially decreased total PCB. We believe that the effect of heat should be investigated more fully.

N. S. PLATONOW and H. S. FUNNELL, Department of Biomedical Sciences; D. H. BULLOCK and D. R. ARNOTT, Department of Food Science; P. W. SASCHENBRECKER, Canada Department of Agriculture, Animal Pathology Laboratory, Guelph, Ontario; and D. G. GRIEVE, Department of Animal Science, University of Guelph, Guelph, Ontario, Canada

References

(1) Arochlor plasticizers. 1965. Tech. Bull., O/PL-306. Monsanto Chemical Co., St. Louis, Missouri.

(2) Bagley, G. E., W. L. Reichel, and E. Cromartie. 1970. Identification of polychlorinated biphenyls in two bald eagles by combined gas-liquid chromatography-mass spectrometry. J. Ass. Off. Anal. Chemists. 53:251.

(3) Bailey, S., P. J. Bunyan, and F. B. Fishwick. 1970. Polychlorinated biphenyl residues. Chem. Industr., p. 705.

TABLE 2. Individual fractions of polychlorinated biphenyls chromatograms, tabulated in increasing order of retention time and expressed as a percentage of the whole.

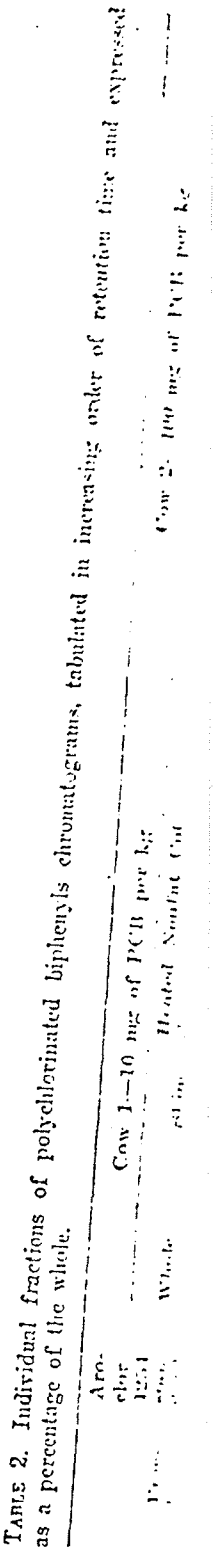

TABLE 2. Individual fractions of polychlorinated biphenyls chromatograms, tabulated in increasing order of retention time and expressed as a percentage of the whole.

Fraction	Aroclor 1254 standard	Cow 1—10 mg of PCB per kg							Cow 2—100 mg of PCB per kg						
		Whole milk	Cream	Skim-milk	Heated skim-milk	Nonfat dry milk	Cottage cheese	Whey	Whole milk	Cream	Skim-milk	Heated skim-milk	Nonfat dry milk	Cottage cheese	Whey
1	9.4	6.1	3.0	7.4	9.2	7.4	7.4	8.4	7.7	2.9	7.2	9.5	7.3	6.9	8.4
2	5.5	2.5	4.4	5.0	5.2	5.2	4.9	5.6	3.2	4.2	5.0	5.4	5.2	4.8	5.4
2a	2.5	0.6	1.2	1.8	1.7	1.7	1.8	1.9	0.9	1.1	1.7	1.8	1.7	1.7	1.9
3	11.8	8.8	9.4	9.8	13.1	12.5	9.5	11.0	9.1	9.2	9.8	13.2	12.4	9.0	11.0
4	11.7	10.7	11.0	10.8	12.6	11.7	10.8	10.9	9.7	10.8	10.8	12.7	11.6	10.9	10.9
5	9.0	8.6	8.8	8.2	8.0	7.3	8.2	8.1	8.4	8.6	8.2	8.0	7.3	8.3	8.2
6	9.9	6.0	8.7	7.4	8.2	7.2	7.3	7.3	6.8	9.0	7.3	8.6	7.3	7.4	7.3
6a	4.5	3.9	4.4	4.6	4.6	3.4	4.5	3.8	4.4	4.5	4.6	4.6	3.4	4.6	3.8
7	8.1	12.9	12.5	12.1	9.1	10.6	12.0	12.1	10.6	12.8	12.1	9.1	10.7	12.1	12.1
8	7.1	9.1	9.7	9.0	8.6	8.9	9.7	8.3	8.7	9.9	9.1	8.5	9.0	9.8	8.4
9	4.5	6.9	5.8	5.6	5.7	3.9	5.5	4.9	6.6	5.9	5.7	5.6	3.9	5.7	4.9
10	8.4	13.2	11.3	10.5	8.0	11.3	10.9	10.1	10.9	11.4	10.6	7.9	11.2	10.9	10.1
11	2.6	3.9	2.9	2.8	1.7	2.6	2.7	2.8	4.1	2.8	2.8	1.6	2.6	2.8	2.8
12	2.1	2.9	2.7	2.1	1.7	2.5	2.0	2.0	3.7	2.6	2.1	1.5	2.6	2.1	2.0
13	1.7	2.2	2.2	1.7	1.1	2.1	1.7	1.7	2.7	2.3	1.7	1.0	2.1	1.8	1.7
14	1.2	1.8	2.0	1.2	1.1	1.7	1.1	1.1	2.5	2.0	1.2	1.0	1.7	1.2	1.1

(4) Biros, F. J., A. C. Walker, and A. Medbery. 1970. Polychlorinated biphenyls in human adipose tissue. Bull. Environ. Contam. Toxicol., 5: 371.

(5) Duke, T. W., J. I. Lowe, and A. J. Wilson Jr. 1970. A polychlorinated biphenyl (Arochlor 1254) in the water, sediment, and biota of Escambia Bay, Florida. Bull. Environ. Contam. Toxicol., 5: 171.

(6) Eller, K. R., and D. F. Othmer. 1964. Encyclopedia of Chemical Technology. Sec. Rev. Ed., 5: 260.

(7) Jensen, S., A. G. Johnels, M. Olsson, and G. Otterlind. 1969. DDT and PCB in marine animals from Swedish waters. Nature, 224: 247.

(8) Koeman, J. H., M. C. Ten Noever De Brauw, and R. H. De Vos. 1969. Chlorinated biphenyls in fish, mussels and birds from the river Rhine and the Netherlands coastal area. Nature, 221: 1126.

(9) Kuratsune, M. 1969. An epidemiological study on Yusho. Fukuoka Acta Med., 62: 513.

(10) Li, C. P., R. L. Bradley, and L. H. Schultz. 1970. Fate of organochlorine pesticides during processing of milk into dairy products. J. Ass. Off. Anal. Chemists, 53: 127.

(11) Lichtenstein, E. P., K. R. Schultz, T. W. Fuhremann, and T. T. Liang. 1969. Biological interaction between plasticizers and insecticides. J. Econom. Entomol., 62: 761.

(12) Mojonnier Bros. Co. Instruction manual for setting up and operating the Mojonnier milk tester. Bull., 101. Mojonnier Bros. Co., Chicago, Illinois.

(13) Platonow, N., and H. S. Funnell. 1971. Anti-androgenic-like effect of polychlorinated biphenyls in cockerels. Vet. Rec., 88: 109.

(14) Platonow, N., P. W. Saschenbrecker, and H. S. Funnell. 1971. Polychlorinated biphenyls in cattle. Canadian Vet. J., 12: 115.

(15) Reynolds, L. M. 1969. Polychlorinated biphenyls (PCB's) and their interference with pesticide residue analysis. Bull. Environ. Contam. Toxicol., 4: 128.

(16) Risebrough, R. W., P. Reiche, D. B. Peakall, S. G. Herman, and M. N. Kirven. 1968. Polychlorinated biphenyls in the global ecosystem. Nature, 220: 1098.

(17) Saha, J. G. 1969. Significance of organochlorine insecticide residues in fresh plants as possible contaminants of milk and beef products. Res. Rev., 26: 89.

(18) Saschenbrecker, P. W., and D. J. Ecobichon. 1967. Extraction and gas chromatographic analysis of chlorinated insecticides from animal tissues. Agr. Food Chem., 15: 168.