Determination of OPCs and PCBs in game meat of different areas

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Abstract

The aim of study was the determination of the organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in game meat. The muscles (*triceps brahii* - TB and *longissimus dorsi* - LD) originated from 12 feral red deer (*Cervus elaphus*) and 12 wild boars (*Sus scrofa*) shot in Slovenia and Poland. OCPs and PCBs are known to be very resistant in the environment. Their lipophilic nature is the reason for their concentration and bioaccumulation in the food chain. In our study the modification of standard method SIST EN 1528 1-4: 1998 was done. Ten OCPs and nine PCBs were determined. Content is dependent on species, muscle and hunt location. In general the content of the sum of OCPs and PCBs was greater in game meat of Poland than Slovenian. Meat of wild boars had a higher content of OPCs and PCBs than feral red deer meat. Slovenian feral red deer has higher content of contaminants in LD than in TB muscle (15.36 ppb vs. 5.36 ppb) while Poland feral red deer has in LD lower (12.51 ppb) content than TB (16.30 ppb).

Introduction

Polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs; aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex, toxaphene, hexachlorobenzene (HCB)) have been identified as environmental contaminants in almost every compartment of the global system (Safe, 1992) and have been defined under the Stockholm Convention on Persistent Organic Pollutants (POPs) (Muir and Sverko, 2006). Residues in soils and biota represent an important source of contamination for game meat and enhance a risk for human consumers. By measuring pollutant concentrations in tissues of game animals, an estimation of bioavailability and bioaccumulation can be made.

Materials & methods

A total of 8 red deer (*Cervus elaphus*) and 8 wild boars (*Sus scrofa*) were included in this study. Half of deer and boars was shot in the forest area in the southern part of Slovenia, near Kočevje, the other part was shot in Poland (precise location unknown) and its meat was imported in our country. Therefore each group was included four animals. Animals from Slovenia, included in the study, were treated in accordance with the provisions of the laws on game and hunting enacted by the Government of the Republic of Slovenia (Official Journal of the Republic of Slovenia, 2004). The carcasses were then frozen and stored in the skin at a temperature of –21 ±1 °C. The carcasses were defrosted at +4 °C for 36-72 h. After defrosting and skinning, samples from the left side of each carcass, across the whole width of the middle sections of the trimmed muscles, were taken from the *triceps brachii* (TB) and between the seventh thoracic and sixth lumbar vertebrae from the *longissimus dorsi* (LD) muscle samples were removed. From all animals the back fat was also taken. The samples were homogenized in a blender, packed into polyethylene bags, frozen and stored at a temperature of –21 ±1 °C until analysis (for a maximum of 7 days). After thawing, the drip from samples was blended into the homogenate. In samples the content of PCB and OCP was determined. The samples were analysed in duplicate. The data for PCB and OCP contents were processed by the repeated measures analysis using the GLM procedure (SAS, 1999). The statistical model included the main effects of species (deer and boars), muscle (TB and LD) and hunt location (Slovenia and Poland), as well as the interaction between hunt location and muscle.

In our study for OCP and PCB determination a standard method SIST EN 1528 1-4: 1998 was modified and adapted for game meat. The modifications were made in the extraction step in which cold extraction technique was replaced with Soxhlet extraction and n-hexane as solvent was used. This modification improved the efficiency of the extraction procedure for samples with high fat content. For the clean-up step of fat the SPE procedure was introduced and using of glass columns filled up with Florisil® was applied. Using this approach the amounts of organic solvents were reduced.

Results and discussion

Table 1. Effects of species muscle and hunt location on content of PCB and OCP (ppb) in game meat

	game	LD-PL	TB-PL	fat-PL	LD-SLO	TB-SLO	fat-SLO
PCB							
PCB 26	red deer	0,45±0,3^{ay}	<0,001^{bx}	<0,001^{bx}	0,34±0,2^{ax}	0,28±0,2^{ax}	0,28±0,2^{ax}
	wild boar	1,24±0,8^{ax}	0,41±0,8^{bcx}	<0,001^{cx}	0,83±0,9^{abx}	<0,001^{cy}	0,41±0,8^{bcx}
PCB 34	red deer	<0,001^{by}	0,14±0,27^{by}	12,40±35,07^{bx}	162,2±301,8^{ax}	<0,001^{by}	<0,001^{bx}
	wild boar	1,17±0,7^{ax}	3,34±2,5^{ax}	1,40±2,6^{ax}	2,19±2,2^{ax}	2,95±2,9^{ax}	12,9±34,9^{ax}
PCB 43	red deer	1,39±0,9^{ay}	<0,001^{bx}	<0,001^{bx}	1,03±0,9^{ax}	1,05±1,0^{ax}	0,65±0,8^{abx}
	wild boar	3,56±2,2^{ax}	1,19±2,2^{bcx}	<0,001^{cx}	2,37±2,5^{abx}	<0,001^{cy}	1,19±2,2^{bcx}
PCB 52	red deer	1,54±0,9^{ax}	<0,001^{cx}	<0,001^{cx}	0,75±0,8^{abx}	0,37±0,3^{bcx}	0,33±0,2^{bcx}
	wild boar	1,51±0,9^{ax}	0,25±0,7^{bx}	<0,001^{bx}	0,51±0,9^{bx}	<0,001^{by}	0,25±0,7^{bx}
PCB 106	red deer	<0,001^{ay}	<0,001^{ay}	<0,001^{ay}	<0,001^{ax}	<0,001^{ax}	<0,001^{ax}
	wild boar	10,45±6,5^{bx}	2,61±2,8^{bx}	1465±902^{ax}	0,66±1,9^{bx}	1,33±2,5^{bx}	11,1±20,5^{bx}
PCB 116	red deer	0,25±0,2^{ax}	0,18±0,3^{ax}	<0,001^{bx}	0,28±0,2^{ax}	0,37±0,2^{ax}	0,28±0,2^{ax}
	wild boar	<0,001^{ay}	<0,001^{ax}	<0,001^{ax}	<0,001^{ay}	<0,001^{ay}	<0,001^{ay}
PCB 153	red deer	0,35±0,2^{ax}	<0,001^{bx}	<0,001^{bx}	0,33±0,2^{ax}	0,31±0,2^{ax}	0,32±0,2^{ax}
	wild boar	<0,001^{ay}	<0,001^{ax}	<0,001^{ax}	<0,001^{ay}	<0,001^{ay}	<0,001^{ay}
PCB 156	red deer	0,39±0,2^{ay}	<0,001^{by}	<0,001^{by}	0,42±0,3^{ax}	0,43±0,3^{ax}	0,43±0,3^{ax}
	wild boar	1,31±0,8^{bx}	4,20±4,5^{bx}	614±379^{ax}	<0,001^{by}	<0,001^{by}	<0,001^{by}
PCB 180	red deer	<0,001^{ay}	6,00±5,3^{ax}	167±402^{ay}	10,4±19,3^{ax}	1,41±4,0^{ax}	5,49±10,2^{ax}
	wild boar	38,7±23,9^{bx}	15,1±11,6^{bx}	2346±1446^{ax}	1,97±2,6^{bx}	3,96±3,9^{bx}	357±488^{bx}
∑ PCB	red deer	4,38±2,7^{ay}	6,32±5,1^{ay}	179±437^{ay}	176±319^{ax}	4,23±3,2^{ax}	7,78±8,8^{ax}
	wild boar	57,9±35,9^{bx}	27,1±19,2^{bx}	4426±2723^{ax}	8,53±6,3^{bx}	8,24±7,2^{bx}	383±522^{bx}
OCP							
HCB	red deer	0,30±0,2^{aby}	0,74±1,0^{ax}	<0,001^{bx}	0,35±0,4^{abx}	0,74±0,7^{ax}	0,26±0,4^{abx}
	wild boar	0,88±0,6^{ax}	0,29±0,5^{bcx}	<0,001^{cx}	0,59±0,6^{abx}	<0,001^{cy}	0,29±0,5^{bcx}
α HCH	red deer	0,92±0,0^{ax}	1,42±1,3^{ax}	12,6±30,6^{ax}	0,63±0,6^{ax}	1,10±0,9^{ax}	0,46±0,6^{ax}
	wild boar	0,58±0,3^{by}	0,79±0,9^{bx}	19,9±11,8^{ax}	1,16±0,8^{bx}	0,99±0,6^{bx}	19,9±29,4^{ax}
γ HCH	red deer	1,29±0,0^{by}	1,57±0,4^{bx}	<0,001^{by}	3,66±4,8^{ax}	1,27±0,6^{bx}	0,58±0,7^{bx}
	wild boar	1,48±0,1^{bx}	1,84±0,4^{bx}	21,4±12,0^{ax}	1,59±0,4^{bx}	1,80±0,5^{bx}	7,84±12,4^{bx}
β HCH	red deer	0,19±0,1^{ay}	<0,001^{ax}	9,88±19,7^{ax}	9,73±17,8^{ax}	0,04±0,1^{ax}	0,07±0,1^{ay}
	wild boar	0,43±0,3^{bx}	0,14±0,3^{bx}	26,7±16,5^{ax}	0,29±0,3^{bx}	<0,001^{bx}	18,9±21,3^{ax}
δ HCH	red deer	1,96±0,0^{ay}	3,18±1,5^{ax}	21,1±13,0^{bx}	1,77±2,3^{ay}	3,28±2,5^{ax}	8,32±12,5^{bcx}
	wild boar	14,5±7,8^{ax}	6,48±7,7^{bcx}	0,75±1,6^{cy}	10,60±8,8^{abx}	3,04±1,4^{cx}	5,72±8,3^{bcx}
β lindan	red deer	0,09±0,2^{bx}	0,41±0,6^{bx}	25,5±15,7^{ax}	0,27±0,3^{bx}	0,49±0,3^{bx}	8,94±15,5^{bx}
	wild boar	0,09±0,2^{ax}	<0,001^{ax}	<0,001^{ay}	0,09±0,2^{ax}	0,09±0,2^{ay}	<0,001^{ax}
γ lindan	red deer	0,59±0,1^{by}	1,49±1,2^{bx}	142±54,8^{ax}	33,5±61,0^{bx}	0,75±0,7^{bx}	28,7±52,1^{bx}
	wild boar	2,77±1,4^{bx}	2,13±0,9^{bx}	146±89,5^{ax}	2,08±1,6^{bx}	1,06±0,9^{bx}	107±113^{ax}
heptachlor	red deer	<0,001^{ax}	<0,001^{ay}	18,9±35,0^{ax}	23,9±44,8^{ax}	<0,001^{ax}	<0,001^{ay}
	wild boar	<0,001^{bx}	0,37±0,4^{bx}	55,5±34,15^{ax}	0,09±0,3^{bx}	0,18±0,3^{bx}	37,3±40,0^{ax}
dieldrin	red deer	0,54±0,2^{bx}	0,81±0,0^{bx}	224±72,3^{ax}	17,8±32,7^{bx}	0,21±0,4^{by}	65,4±121^{bx}
	wild boar	0,21±0,4^{bx}	4,09±6,1^{bx}	1,30±2,4^{by}	8,48±6,1^{bx}	3,01±2,4^{ax}	519±885^{ax}
DDD 4,4	red deer	0,63±0,4^{ax}	0,83±0,5^{ay}	9,24±26,2^{ax}	0,69±0,4^{ax}	1,01±0,1^{ax}	0,73±0,5^{ax}
	wild boar	<0,001^{ay}	<0,001^{ax}	0,11±0,3^{ax}	0,11±0,3^{ay}	0,21±0,4^{ay}	9,24±26,2^{ax}
∑ OCP	red deer	6,49±0,4^{by}	10,5±5,6^{bx}	463±51,3^{ax}	92,4±158^{bx}	8,86±4,9^{bx}	114±200^{bx}
	wild boar	21,0±9,4^{bx}	16,1±15,5^{bx}	271±160^{by}	25,1±17,3^{bx}	10,4±2,9^{bx}	726±1003^{ax}

LD – m. *longissimus dorsi*, TB – m. *triceps brachii,* PL – Poland, SLO – Slovenia; ^{a,b,c,d,e} groups with different letters in the index within the row are different ($P < 0.05$); ^{x,y} groups with different letters in the index within the column are different ($P < 0.05$).

The means ± standard deviations for the presence of PCB and OCP (ppb) in game meat and levels of the significance for the differences between red deer and wild boars meat, between LD, TB and fat, and between two hunt locations (Slovenia and Poland) are presented in Table 1. In our study were determined nine different PCBs (PCB 26, PCB 34, PCB 43, PCB 52, PCB 106, PCB 116, PCB 153, PCB 156 and PCB

180) and ten OCPs (HCB, α HCH, γ HCH, β HCH, δ HCH, β lindan, γ lindan, heptachlor, dieldrin and DDD 4,4). PCBs are lipid-soluble components; consequently their content in wild boar meat was significantly higher than in read deer meat (818 ppb *vs.* 63 ppb). Difference in OCP content between different species ? was not significant (178 ppb *vs.* 116 ppb). Generally higher content of PCBs in animals of Poland origin was found compared to Slovenian origin (738 ppb *vs.* 98 ppb), but quite similar content of OCPs (131 ppb *vs.* 163 ppb). A considerable amount of PCBs and OCPs in back fat than in LD and TB muscles were found and the difference between muscles of both hunting locations was not statistically significant.

On the basis of free fatty acid composition (data not presented) of all samples in our study can be assumed that animals were feed different plant species with different amount of OCP and PCB. In game meat from Poland the highest content of PCB 180 (429 ppb), PCB 106 (246 ppb) and PCB 156 (103 ppb) was found, in Slovene game meat was PCB 180 (63 ppb) and PCB 34 (30 ppb) determined in higher level. PCB 34 and PCB 180 were loaded in great extend in deer; in Polish deer was prevalent PCB 180 (57 ppb) and in Slovene dear PCB 34 (54 ppb). Just the opposite was found in boars where in Slovene animals the highest content of PCB 180 (120 ppb) was accumulated. But in case of Polish boars besides of PCB 180 (800 ppb) also PCB 106 (492 ppb) and PCB 156 (206 ppb) were accumulated.

Generally in game meat of Polish and Slovene origin in significant amounts following OCPs were found: dieldrin (39 ppb *vs.* 102 ppb), γ lindan (49 ppb *vs.* 29 ppb) and heptachlor (13 ppb *vs.* 10 ppb). Game meat of Slovene origin was contaminated with the highest conc. of dieldrin and γ lindan, Polish deer with dieldrin, and boars γ lindan. Significant difference between origins was found presumably due to different use of OCPs in different countries and legislation on pesticide use (what kind of and in which quantity) in environment.

When game was compared to beef – 0.47 ppb, pork – 0.38 ppb and poultry – 0.46 ppb; MeeKyung (2004)) it was found that game contained significantly higher content of PCBs as other animals (red deer 150-times more, wild boars 2000-krat more). Different feeding habits of cattle compared to game (uncontrolled feeding-stuff, free-living manner of life) entailed observed differences.

The consensus values by WHO (1998) for toxic equivalent potencies (TEF values) of PCBs are 30-90 pg TEF/g of fat, 6-18 ng TEF/kg of human body mass. TEF values for PCB, calculated on basis of this study, are 1.8 pg/g for deer meat both origin, as for boar's meat from 3.9 pg/g to 45.1 pg/g (Slovene and Polish origin), respectively.

In spite of long-term PCB-use in open systems prohibition and continual warning of their danger for environment and consequently for human, there was found quite high content of PCBs and OCPs in game meat.

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